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ASTM BULLETIN

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AMERICAN SOCIETY for TESTING MATERIALS

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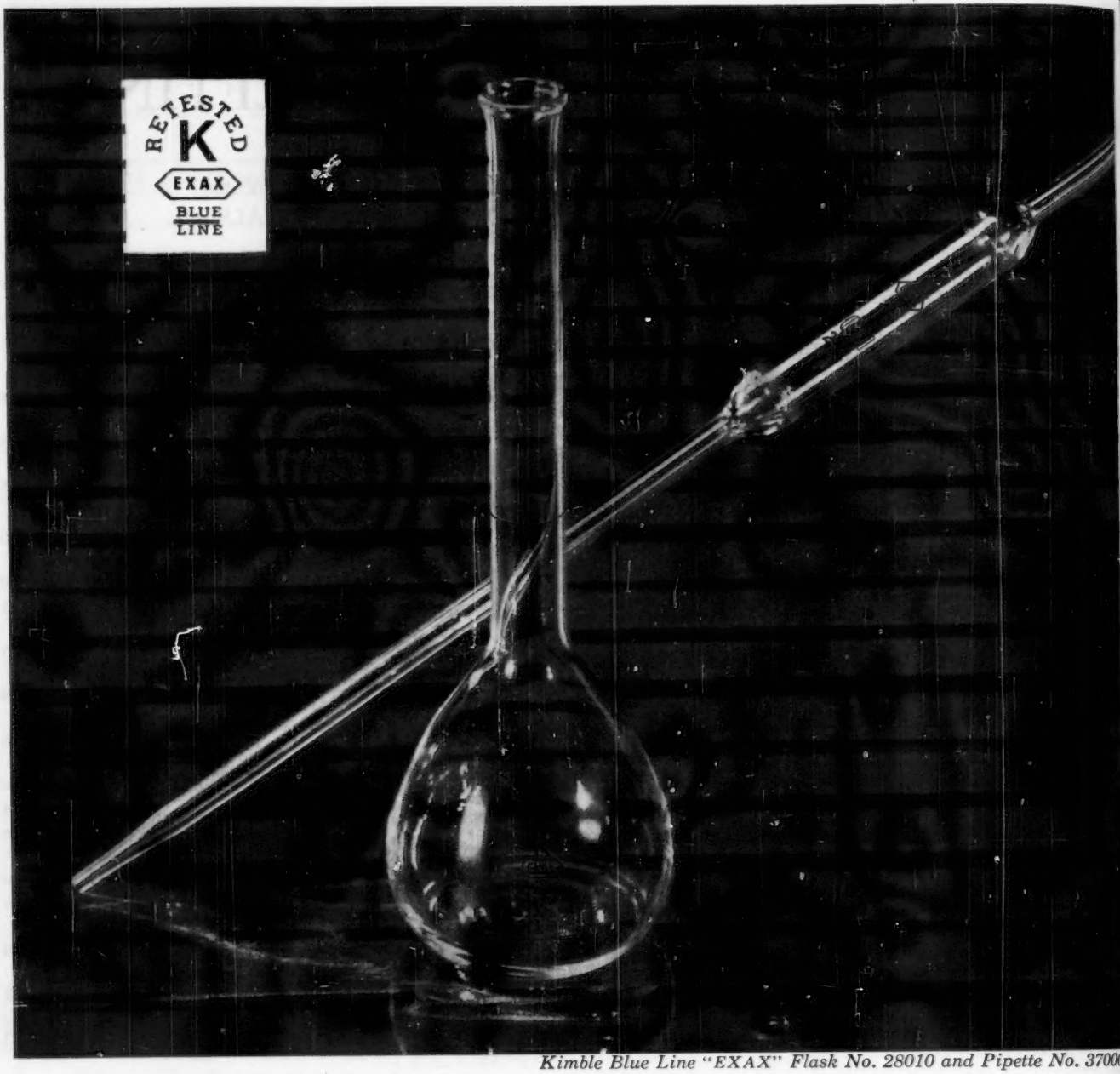

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ASTM BULLETIN

"Promotion of Knowledge of Materials of Engineering, and Standardization of Specifications and Methods of Testing"

TELEPHONE—Rittenhouse 6-5315 | R. E. Hess, Editor
R. J. Painter, Associate Editor | CABLE ADDRESS—TESTING

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Technical Sessions, Committee Meetings, Exhibits, Promise Busiest Annual Meeting

Main Registration, Apparatus and Photographic Exhibits at Book-Cadillac Hotel, Week of June 21. Some Sessions and Numerous Committee Meetings at Cooperating Hotels

DESPITE the fact that business meetings of the Society are on an annual basis, and they seem to come around with what might be thought monotonous regularity, each of these meetings is a distinct and thoroughly different affair. The technical sessions and the various symposiums cover quite different subjects from year to year; and the technical committee meetings, while they may review some of the past progress, primarily are aimed at aggressively solving testing and materials problems and are not passive or static in spirit. Every two years there is an Exhibit of Testing Apparatus and Related Equipment, these exhibits affording members and the large number of visitors an excellent opportunity to see what is new in this industry so vital to work in materials.

Of course, all the foregoing might be considered a "come on" for the 1948 Annual Meeting in Detroit the week of June 21. As the manufacturer or seller of a good product need have no compunctions in promoting his products, we feel the importance of an A.S.T.M. annual meeting cannot be stressed too strongly. Not from the object of drawing more numbers, but from the opportunity afforded our members to plan and work in the interest of A.S.T.M. (and consequently the interest of industry and government), and also of association with their fellow members and fellow engineers, sharing knowledge and getting real satisfaction from participating in a thoroughly democratic and cooperative program.

In a news article of this kind we can but note a few highlights of the meeting, and advise members to be on the lookout for the May ASTM BULLETIN, late in that month, for the complete provisional program and details. Some pertinent information follows.

SYMPOSIUMS AND TECHNICAL SESSIONS

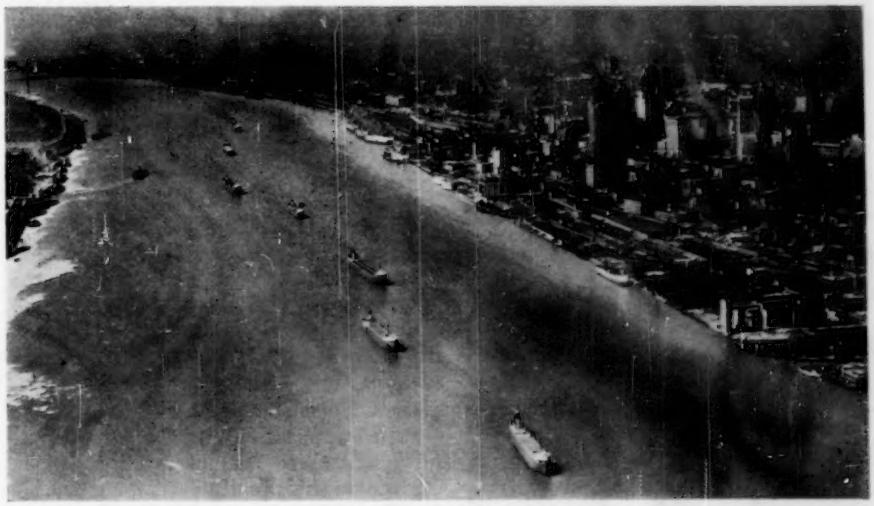
The technical program planned for the meeting under the general supervision of the Administrative Committee on Papers will be a very diverse one and extremely interesting to segments of our members and committee people. Each of the 1948 Symposiums noted below includes a number of technical papers. In fact, adding the technical papers in the symposiums to the so-called separate papers, also noted below, there are more than 100 to be presented. Following certain symposiums the designations of technical committees which are sponsoring them are given.

SYMPOSIUMS AND SPECIAL SESSIONS

Mineral Aggregates
Magnetic Testing (A-6)
Metallography in Color (E-4)
Functional Tests for Ball-Bearing Greases (D-2)
Usefulness and Limitation of Samples (E-11)
Speed of Testing (E-1)
The Influence of Non-ferrous Metals and Their Compounds on the Corrosion of Pressure Vessels (D-19)
Effect of Temperature
Deformation of Metals as Related to Forming and Service (Administrative Committee on Simulated Service Testing)
Test Methods and Procedures Used in Identifying Reactive Materials (C-9)
Non-Destructive Tests (E-7)
Quality Control of Materials (E-11)

TECHNICAL PAPERS

In addition to the symposiums there will be a number of technical sessions devoted to the presentation of separate papers, and a large number of committee reports. These papers and reports will will be grouped appropriately according



Empty ore carriers going North in the Detroit River for another load. Millions of tons of iron ore use this route. Not often are so many carriers seen in the river at one time.

to the materials and fields involved. Some of the subjects to be covered are included in the following list:

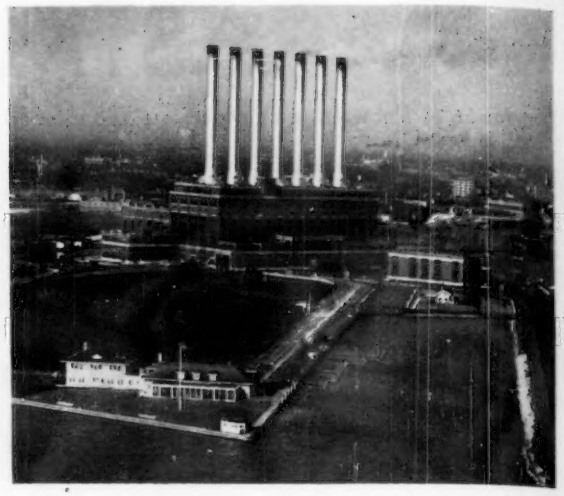
Atmospheric durability of steel, corrosion testing of low alloy steels, corrosion tests of iron and steel pipes, fatigue strength and notch sensitivity of steel, fatigue properties of heat-resisting cast iron, studies of transition temperature of metals, dynamic stressing above the endurance limit, fatigue characteristics of copper, magnetism in copper alloys, creep of extruded lead, properties at elevated temperatures of magnesium-base alloys, plastic coatings for steel, quantitative evaluation of corrosive conditions, resistance of concrete to freezing and thawing, bond strength of concrete, effect of aggregates on the strength of concrete, concrete durability as affected by coarse aggregates, spectrochemical analysis of mineral aggregates, strength of bond of brick-mortar assemblages, resistance of brick buildings to moisture penetration, ignition point of solid fuels, testing surface waterproofers, creep of laminated plastics, requirements of engine antifreeze, study of the kinetics of oil oxidation.

Entertainment Program

An interesting program is being planned for the wives and families of A.S.T.M. members who will be in Detroit during the annual meeting. The Detroit Council through its General Committee on Arrangements, which is responsible for a number of the events during the meeting, has just announced the appointment of a Hostess Committee functioning under the general direction of C. E. Heussner of the Chrysler Corp. who is chairman of the Annual Dinner and Ladies' Entertainment. Mr. Heussner will have the aid of the following ladies who will constitute the Hostess Committee:

Mrs. T. A. Boyd
Mrs. Van M. Darsey
Mrs. F. J. DeWitt
Mrs. L. B. Case
Mrs. C. H. Fellows
Mrs. Wm. R. Fraser
Mrs. W. H. Graves
Mrs. C. E. Heussner
Mrs. J. D. Klinger
Mrs. H. A. Wagner
Mrs. Albert E. White
Mrs. R. B. Saltonstall

The tentative plans of this group call for a "get-acquainted" tea, a dinner dance, luncheons, and trips to points of interest.



Conners Creek Generating Station of the Detroit Edison Co. This and several other modern stations supply Detroit's tremendous needs for electrical energy.

Aside from the dinner dance to be held on Wednesday evening, June 23, there will be no entertainment, as such, for the men at the meeting. With committee meetings, technical sessions and the exhibits, and other matters, most of the men will have a very busy time indeed. However, the Detroit Committee plans that if there are any particular plants or places which members or committee members would like to visit on the occasion of their stay in Detroit for the annual meeting, the attempt will be made to arrange for such visits. Franz P. Zimmerli, of the Barnes-Gibson-Raymond Division of Associated Spring Corp., is the chairman of the group responsible for this, and further announcements will be made.

Dr. Paul Aebersold

"Isotopes and Their Application in the Field of Industrial Materials" to be Subject of Marburg Lecture, Thursday, June 24

A real treat is unquestionably in store for all those members and others interested in materials who can be present at the Rackham Engineering Building, Detroit, on Thursday evening, June 24, when the 1948 Edgar Marburg Lecture is delivered. Paul C. Aebersold, Chief of the Isotopes Division, Atomic Energy Commission at Oak Ridge, Tenn., will speak on the very timely subject of "Isotopes and Their Application in the Field of Industrial Materials." An outstanding authority in the field, he is intimately connected with the use of isotopes in their varied applications, and much interesting and up-to-date information will be given on this rapidly developing field.

The lecture is being held at Rackham, which is a short taxi or trolley ride from downtown Detroit, in order to have use of the large auditorium and thus take care of the large audience expected. For the first time in many years the lecture is scheduled for Thursday evening of Annual Meeting week, this time being selected to dovetail best with the numerous meeting activities. While a further statement on the subject of the lecture will appear in the May Bulletin, Dr. Aebersold points out that "the use of isotopes in the field of industrial materials is potentially a great one. As tracer atoms they may be used in research aimed at improvement of material and increased efficiency of production. They are already being used widely in investigations covering such varied topics as friction, oil well-logging, ventilation, steelmaking, vulcanization, polymerization, welding, corrosion, catalysis, diffusion, chemical

exchange, and pharmaceutical syntheses.

"Tracer atoms may also be used in routine process control. Such uses are largely still in the development stage. In the case of process use of radioisotopes, the handling methods and levels of activity would have to be safe from the standpoint of industrial hygiene and public health. Incorporation of unsafe amounts of activity in marketed products would have to be avoided. Stable isotopes would not involve health-safety problems but they would not in general be as readily adaptable to continuous process measurement."

A graduate of the University of California, where he obtained his M.A. degree in 1934, and his Ph.D. degree in '38, in the Radiation Laboratory he was closely associated for many years with Dr. E. O. Lawrence, Nobel-prize winner. He is thus a pioneer worker in the field of production and application of radioisotopes, and his long experience in problems of radiation physics and radiation protection place him among the top authorities in this field.

Question and Answer Period

For the first time since the Marburg lectures were started in 1926, there is to be a "question and answer" period following this lecture. It was felt that a number of those in the audience would have pertinent questions on which Dr. Aebersold would care to comment, and he has gladly assented to do this. Furthermore, Dr. Aebersold himself is desirous of having this discussion so that he can become more familiar with the problems and interests of individuals in different fields of work.

See the May BULLETIN for further details, and get to the lecture hall in Rackham early.

Downtown Detroit Looking East Toward the River and Belle Isle. Windsor, Canada, is across the river.

Wide Range of Testing and Research Instruments, Laboratory Supplies and Related Equipment to Be Shown at Detroit Exhibit

DURING the week of June 21, at Detroit's Book-Cadillac, which is the main headquarters hotel for the annual meeting, some 50 leading manufacturers and distributors of testing instruments, equipment used in research, and laboratory supplies of all kinds will display and demonstrate new and improved items. This year's A.S.T.M. Exhibit will be in the Ballroom and Italian Garden of the Book with the main A.S.T.M. Registration Desk immediately adjacent. The exhibitors will show not only instruments and supplies used in A.S.T.M. standards, but will also stress the tremendous range and variety of equipment used in evaluating all kinds of materials and products.

The May BULLETIN will include brief descriptions of displays to be sponsored by each company and thus will provide an excellent preview of what can be expected.

The Exhibit affords A.S.T.M. members and thousands of others interested an excellent opportunity to see just what equipment is available and gives a firsthand view of new developments of which there are a great many in the industry.

There has been practically a complete sellout of available space, but the Exhibit booths have been so arranged that there is ample aisle space and plenty of "elbow room."

An advance list of the companies participating in the Exhibit follows:

LIST OF 1948 EXHIBITORS

American Instrument Co.
American Machine & Metals, Inc.
Atlas Electric Devices Co.
Baldwin Locomotive Works
Bausch & Lomb Optical Co.
Brookfield Engineering Labs.
Buehler, Ltd.
Burrell Technical Supply Co.
Carboloy Co., Inc.
Central Scientific Co.
Clark Instrument, Inc.
Consolidated Engineering Corp.
Corning Glass Co.
Detroit Testing Machine Co.
Harry W. Dietert Co.
Eastman Kodak Co.
Eberbach & Son Co.
Gamma Scientific Co.
General Electric Co.
General Radio Co.
Hanovia Chemical and Mfg. Co.
Illinois Testing Labs.
Jarrell-Ash Co.
Kewaunee Manufacturing Co.
Kimble Glass Division of Owens-Illinois Glass Co.
King Refrigeration Co.
Laboratory Equipment Corp.
Lancaster Iron Works, Inc.
Leeds & Northrup Co.
Magnaflux Corp.
National Spectrographic Labs.
Tinius Olsen Testing Machine Co.
Parr Instrument Co., Inc.
Phipps & Bird, Inc.
Precision Scientific Co.
Rainhart Co.
E. H. Sargent & Co.
Scott Testers, Inc.
Sperry Products, Inc.
C. J. Tagliabue Corp.
Waukesha Motor Co.
Wilson Mechanical Instrument Co.

A cordial invitation is extended to anyone genuinely interested in the field of materials and in the equipment being displayed to attend. There is no charge, but those who are not attending the A.S.T.M. meeting will be asked to fill out a registration card on going into the Exhibit.

There will be an A.S.T.M. booth in the Exhibit with a complete display of publications, information on the Soci-

ety's activities and charts on standards, specifications, and the like.

Photographic Exhibit:

Adjacent to the Apparatus Exhibit, the 1948 Photographic Exhibit will be staged. A special committee in Detroit headed by F. G. Weed, Rinshed-Mason Co., is sponsoring the Photographic Exhibit and Committees E-4 on Metallography and E-7 on Radiographic Testing are sponsoring divisions relating to their fields of work. All A.S.T.M. members and committee people who are interested are invited to submit prints. A photographic blank—entry form will be distributed shortly to each member. This gives full details.

Detroit

Some Historical Highlights:

● Deriving its name from its situation ("de troit" from the French, meaning "of the strait" and referring to the river connecting Lake Erie and Lake St. Clair), Detroit has had a colorful and stimulating history since its founding in 1701 by the French explorer Cadillac as an outer bastion to the fur-trading activities of earlier, more northerly settlements.

● At the close of the French and Indian War, it was surrendered to the British, remaining in their possession until 1783 when the American flag rose from its battlements. During the War of 1812, it again passed into the hands of Great Britain for a brief period. Street and place names reflect this French, British, and Indian ancestry, and two centuries of cultural development under three flags have left a permanent imprint upon the character of the community.

● Historic records indicate that the first session of governing officials in Michigan Territory was held in Detroit in 1805; the first bank was opened in 1806, its first president being Judge Augustus B. Woodward, for whom Woodward Ave. was named. The last Indian hostilities were witnessed in 1814–1815, and its first and only whipping post, erected in 1818 to rid the town of petty thieves and vagabonds, was secretly removed by unknown parties in 1830.

● For nearly 60 years every main thoroughfare leading to Detroit was a toll road, and at night it was necessary to awaken the gatekeeper to enter or leave. The Detroit *Gazette* issued its first number in 1817; the first theatrical performance was held atop a government warehouse in 1819; the Detroit and Pontiac Railway, the first chartered railway in the West, built its Detroit Terminal in 1836.

● The next two decades saw the establishment of the first school and hospital, and the building of the first government-owned postoffice building. Subsequently the city grew apace but received its great industrial impetus at the turn of the century with the rise of the motor industry, following Ford's experimentation with the automobile in a little brick one-story building in the rear of a rented home on Bagley Ave.

● Now, as the fourth largest city of our country, with its 2500 manufacturing establishments, it may truly be called a metropolis of great industries; and hand in hand with its industrial progress it has become a city enriched by its all-pervading treasures of art, education, and religion—preserving the spirit of its sacred history while moving with ever-quickening pace across the scenes of its great industrial perspectives. With its attractive homes, and spacious and numerous parks, it may likewise truly be termed a beautiful city, offering much of interest and appeal to visitors.

Industry:

● As the motor capital of the world, the Detroit area produces over ninety per cent of all passenger automobiles built in America, over sixteen makes of cars being represented in this output. Its other industries are many and various. Located within its confines are leading stove, adding machine, pharmaceutical and chemical, and electric refrigerator manufacturing plants, as well as leading copper and brass rolling mills. It also ranks high in the production of salt and salt products, marine engines, paints and varnishes, freight cars, vacuum cleaners, twist drills, seeds, and a large variety of manufactured products of world usage.

● Research laboratories maintained by certain of the automobile manufacturers are among the largest in any industry in the world. The Detroit area also boasts one of the most modern steel plants, cooperating in meeting the requirements of the automobile, refrigerator, furniture, and other manufacturers.

Places of Interest:

● With its unique location, its tremendous industrial activity, its beautiful buildings—cultural and industrial, its acreage of parks and parkways, and various recreational pursuits, Detroit's points of interest are practically unlimited.

● Motorists may drive to Canada *via* the Ambassador Bridge, the Detroit-Canada Tunnel, or Walkerville-Detroit Ferry. The Ambassador Bridge offers a magnificent view of Detroit, the river, and the border cities and Canadian countryside.

● Belle Isle, Detroit's beautiful 1000-acre island park, may be reached by bus or street car to Belle Isle Bridge, and thence by bus to the island.

● A visit to the Art Center, an imposing group of white marble buildings, comprising the Institute of Arts, Main Library, and the Rackham Memorial Building, is included in the program of most tourists, and visits to the Detroit Historical Museum and famous Fisher Theatre are considered well worth while.

● Probably one of the most frequently visited centers is the famous Greenfield Village, with the Ford Museum, depicting American history, and the adjacent Dearborn Inn; and tours of Ford Motor Co., the several Chrysler Corporation plants, and the General Motors buildings are usually covered by those interested in industrial progress.

Members and Committee Members are receiving in a separate circular information on hotels. Full details for making reservations are given.

Much New Work on Standardization and Research in Materials Covered at 1948 Committee Week

300 Meetings in Washington; Actions Briefed

At the some 300 meetings of A.S.T.M. main technical committees and their subgroups and sections during 1948 A.S.T.M. Committee Week in Washington, D. C., March 1–5, inclusive, many new specifications and test methods were reported, a great amount of research work was discussed and planned, all of which will be of widespread interest to engineers and technologists concerned with materials. This concentration of technical committee meetings during one week enables the members of different committees to attend the various sessions which are scheduled, with a considerable saving in time and expense.

Because of the large number of meetings and the heavy attendance totaling about 1100, it was necessary to use several different hotels.

Many of the actions covered at the meetings are subject to letter-ballot and will be covered in detail in the committees' reports to be presented at the Society's annual meeting in Detroit, the week of June 21. Some of the recommendations will be approved before that time through the A.S.T.M. Administrative Committee on Standards which can act for the Society in determining whether a consensus has been reached in the technical committees.

A list of the major technical committees which met in Washington is shown below—most of these having numerous subcommittee and section meetings.

Practically every one of the committee meetings was well attended by representatives of both consumers and producers of the materials involved.

In line with the usual practice of requesting officers of the technical committees to supply information on the major developments at the committee meetings to be used as the basis for news accounts in the BULLETIN, there appears on the following pages information which it is believed will be of interest to many of the members. There was intensive activity at all of the meetings and a review of the developments as indicated below will make clear to those concerned just how much activity is under way in the fields of standardization and research. These accounts cover not only meetings held in Washington during Committee Week but several groups which have met recently in other cities.

Letter-Ballots:

For the most part all of the recommendations noted will be referred to the various committees for letter-ballot before formal recommendation to the Society and this situation should be kept in mind in reviewing the proposed actions. Members will be given further information through the preprints of reports which will be distributed this year, as previously, in advance of the annual meeting, these reports covering the many actions which committees will bring up at the annual meeting in Detroit, June 21 to 25.

LIST OF COMMITTEE MEETINGS

A-1 on Steel (Philadelphia)
A-3 on Cast Iron
A-5 on Corrosion of Iron and Steel
A-6 on Magnetic Properties
A-7 on Malleable-Iron Castings
A-9 on Ferro-Alloys
A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys
Advisory Committee on Corrosion
B-2 on Non-Ferrous Metals and Alloys (Subcommittees)
B-3 on Corrosion of Non-Ferrous Metals
B-4 on Electrical Heating, Resistance and Related Alloys (Philadelphia)
B-5 on Copper and Copper Alloys
B-6 on Die-Cast Metals and Alloys
B-7 on Light Metals and Alloys
B-8 on Electrodeposited Metallic Coatings
B-9 on Metal Powders and Metal Powder Products (New York)
C-2 on Magnesium Oxychloride Cement
C-8 on Refractories
C-11 on Gypsum
C-12 on Mortars for Unit Masonry
C-15 on Manufactured Masonry Units
C-16 on Thermal Insulating Materials
C-17 on Asbestos-Cement Products
C-18 on Natural Building Stone
C-19 on Structural Sandwich Constructions
D-1 on Paint, Varnish, Lacquer, and Related Products
D-2 on Petroleum Products and Lubricants
D-3 on Gaseous Fuels (Subcommittees)
D-4 on Road and Paving Materials
D-5 on Coal and Coke
D-8 on Bituminous Waterproofing and Roofing Materials
D-9 on Electrical Insulating Materials (Dayton)
D-11 on Rubber and Rubber-Like Materials
D-13 on Textile Materials (NewYork)
D-14 on Adhesives
D-15 on Engine Antifreezes (Detroit)
D-18 on Soils for Engineering Purposes
D-19 on Water for Industrial Uses
D-20 on Plastics (Dayton)
E-1 on Methods of Testing
E-3 on Chemical Analysis of Metals
E-4 on Metallography
E-5 on Fire Tests
E-6 on Methods of Testing Building Constructions
E-7 on Radiographic Testing (Advisory)
E-9 on Fatigue

Committee A-1 on Steel

While the problem of specification requirements for materials for use at subatmospheric temperatures was probably the one most discussed at the series of meetings of Committee A-1 during its three-day session in Philadelphia February 2–4, there was notable activity in a number of other fields. Committee A-1 did not participate in A.S.T.M. Committee Week during the first week in March in Washington, but even so, there were some 20 meetings of subcommittees, and the main group. The Advisory Committee under the chairmanship of N. L. Mochel, Westinghouse Electric Corp., at a five-hour session reviewed a number of administrative matters.

Personals:

It was announced that H. G. Miller, Mechanical Engineer, Chicago, Milwaukee, St. Paul and Pacific Railroad Co., Milwaukee, Wis., had accepted appointment as chairman of the important Subcommittee XI on Steel for Boilers and Pressure Vessels, succeeding E. J. Edwards, American Locomotive Co., Schenectady, who had wished to be relieved after more than 25 years as chairman; and W. Warner, Inland Steel Co., Chicago, will be associated with Mr. Miller in the operation of the committee, serving as secretary. C. E. Loos, Manager, Structural and Plate Bureau, Metallurgical Division, Carnegie-Illinois Steel Corp., Pittsburgh, was appointed vice-chairman of Subcommittee II on Structural Steel for Bridges, Buildings and Rolling Stock.

Actions Approved:

As a result of work which Committee A-1 did in late 1947, the Society has recently approved new specifications for Stress-Relief Annealed Cold-Drawn Carbon-Steel Bars (A 311 – 47 T). The material covered is suitable for applications where high strength, good machinability, and a minimum of distortion are important.

Several revisions to clarify the intent of the words "lot," "heat number", etc., and to state further in a clear fashion, requirements on number of tests, were incorporated in three pipe specifications for service at high temperatures—Alloy-Steel (A 158), Carbon Molybdenum (A 206), and Chromium-Molybdenum (A 280).

Major revisions were approved in the Tentative Specifications for Alloy Castings for High Temperature Service (A 217) with five new grades added. These have come into rather extensive use, and the committee felt standardized requirements should be set up. The new alloys covered include molybdenum-vanadium, nickel-chromium-molybdenum, chromium-molybdenum (2 grades), and carbon-molybdenum.

A new grade of steel for forged pipe, flanges, and fittings, for high-temperature service, of 1 per cent chromium-½ per cent molybdenum is to be added to the Standard A 182, thus providing a grade similar to the new pipe specification A 315, and this same minimum composition.

Work Under Way:

It was announced that a specification covering bolting materials for service at low temperatures has had some additional editorial modifications incorporated. This will be referred to A.S.T.M. for approval and publication. Certain other changes will be recommended in the specifications for alloy steel bolting for high-temperature service (A 193) and also for nuts (A 194).

The bar committee (Subcommittee XV) which has completed several specifications in the last year or two, and has an active program still under way, has approved requirements for heat-treated carbon-steel bars, and is starting on a draft of requirements for alloy-steel bars with the purchase requirements to be based largely on chemical composition. The various specifications in this field, including the two basic original items A 107 (hot-rolled carbon bars) and A 108 (cold-finished bars and shafting) are intended to serve the needs of a wide range of purchasers in various fields—railroads, electrical manufacturing, machine work, and a great many smaller users.

The standards facilitate stocking of material, and where physical property requirements are essential, enable the buyer to have a specific idea of just what he has or is ordering.

Another new project involves requirements for steel sheets of boiler and firebox quality. This subcommittee (XIX) also is studying the desirability of standardizing requirements for certain type of tests.

The group concerned with springs and spring wire is investigating a twist test which might be desirable in some instances. As a result of earlier work, this subcommittee has had its standard tension test for spring wire approved by the A-1 group concerned with physical tests and it will be submitted now to the main committee.

In the field of forgings, the subcommittee has an extensive study under way which will result in a complete overhauling of at least four of the important specifications covering carbon- and alloy-steel forgings for railroads and industrial uses. These specifications have not had any major changes for a number of years and in the meanwhile new grades and requirements have come into use.

A macroetch test for forgings which would be applicable particularly to products covered in Specifications A 235 through A 238 has been completed, and will be referred to the Society for publication. The committee agrees that this is not the final answer on requirements for macroetch testing, but it is a step forward and will meet many immediate needs.

The subcommittee (II) concerned with structural steel for bridges and buildings has had assigned to it for study and review the standard covering steel for ships, A 131. This group has an interesting project well under way involving the establishment of a general specification incorporating tolerances, permissible variations, and material generally that is common to the group of structural steel specifications. This anticipates that the product specification, say for bridge steel, would be a very compact document, covering only chemistries, physicals, and such essential items, with reference made to all or some parts of the general specification. A proposed general specification draft has been completed with its large number of tables and related material, and a revised specification for structural steel for bridges and buildings, A-7, has been drafted in the new form which it would assume.

It is expected that these two documents will be published for information and comment and final decision on their disposition will be reached at the June meetings in Detroit.

An important change in the requirements for wrought wheels for electric service is to be recommended for adoption. This involves the requirement that the carbon content shall be in the range 0.65–0.80 per cent on check analysis.

Committee A-3 on Cast Iron

In considering the Proposed Tentative Methods of Impact Testing, Committee A-3 decided to describe the "drop," "Izod," and "Charpy" tests as presently modified to permit testing cast iron. Final revision of the proposed Tentative Specifications for Gray Iron Castings for Non-Pressure Containing Parts at Elevated Temperatures was passed for letter-ballot.

In regard to the Specifications for Gray Iron Castings for Pressure Containing Parts for Temperatures up to 650 F. (A 278) and the new proposed tentative for nonpressure applications, it has become clear that additional information on creep strength of various cast irons is desirable. It was decided to make a survey to determine if sufficient funds can be raised by Committee A-3 to finance such a program. Consultation with the Joint Research Committee on Effect of Temperature on the Properties of Metals was suggested and approved.

Mr. J. S. Vanick, as chairman of the Research Committee of Committee A-3, reported on a survey of the uses of such instruments as SR gages in studying stresses in iron castings. He reported that a number of producers use these gages and stress coatings, and a symposium on this subject was suggested, possibly for the 1949 annual meeting. It would include a number of short papers describing the purpose of using the gages, and whether the result was effective or not in perfecting engineering design.

Committee A-5 on Corrosion of Iron and Steel

Committee A-5 is cooperating with Committee B-8 which is making some check tests of the Method of Test for Local Thickness of Electrodeposited Coatings (A 219) and development work is proceeding on proposed revisions in the Specification for Lead-Coated Hardware. A subcommittee is considering the possible inclusion in the Method of Test for Weight of Coating of Zinc Coated (Galvanized) Iron and Steel Articles (A 90) of an additional stripping method in which hydrochloric acid diluted with an equal amount of water is used. It is claimed that this method will permit making rapid checks on the shop floor. The Method of Test for Uniformity of Coating by the Preece Test (A 239) is being reviewed to clarify the definition of the end point. The incorporation into many specifications, in spite of its somewhat limited accuracy and its inapplicability to some types of coating, of the Hull-Strausser method for determining thickness of coating has caused the subcommittee to decide to confer with representatives of Committee B-8 and of the Bureau of Standards to see whether some action is not needed to prevent further misuse of this method.

Minor changes have been proposed in the Specification for Galvanized Iron or Steel Sheets (A 93). Most of these are of an editorial nature intended to bring the method into accord with present practice. Because of abuse of privileges granted in this specification under the clauses requiring the manufacturer to stand the cost of test, changes are proposed so that production will not be held up for inspection when such inspection is not made promptly. The present Specifications for Farm Field and Railroad Right of Way Fencing (A 116) and for Iron and Steel Barbed Wire (A 121) are being revised to reduce the sizes and styles to those now called for in the Department of Commerce Simplified Practice Recommendation R9-47, which covers the products now produced commercially.

The subcommittees covering the exposure testing of sheets, wire and hardware have conducted their usual inspections the results of which will be published in the annual report. The Key West test site had to be re-located because the property on which it was placed was acquired by the County from the government for a public bathing beach. The new site is located in the Navy area at Fort Taylor. In this move some of the hardware specimens were discarded as they had served their useful life. These, in general, were in groups which had already been removed from other test sites.

The Subcommittee on Hardware plans to make a more thorough review of the need for an extension to the hardware exposure test before proceeding further with its program. In the past it has been felt that the limitation of the exposure test specimens to materials coming within the scope of A-5 has reduced interest in and the usefulness of the test. A check will be made with other committees which may be interested in hardware, to see whether a testing program covering the exposure of specimens with base materials other than iron or steel and with other than metallic coatings for finish may not be advisable, rather than the somewhat limited program heretofore considered by A-5.

Committee A-6 on Magnetic Properties

Committee A-6 noted, with regret, the recent death of K. L. Scott of the Western Electric Co., a loyal and active member of the committee since 1930.

Plans were discussed for a Symposium on Magnetic Testing to be presented during the week of June 21 at the Annual Meeting of the Society in Detroit. Ten papers have been offered for this symposium which it is planned to publish together with their discussion as a separate booklet. The committee is contemplating a thoroughgoing rearrangement and revision of its standards relating to magnetic testing (A 34). A small group is now working on the part covering primarily tests of permanent magnet materials.

The Subcommittee on the Correlation of Magnetic Testing and Methods reported good progress in the collection and standardization of a set of standard reference specimens which will eventually be available for circulation among the members of the committee.

Committee A-7 on Malleable Iron Castings

During the meeting of Committee A-7 the Special Committee, appointed to review the Specification on Flanges, Fittings and Valve Parts (A 277), arrived at a concensus that changes in new types of fitting application made it wise to leave this specification as tentative without change. Other subcommittees proposed revisions in the Specification for Malleable Iron Castings (A 47) and for Pearlitic Malleable Iron Castings (A 220) which recognize continuous foundry operations and adapt inspection methods to them. These actions were all approved by the main committee, subject to letter ballot.

Committee A-9 on Ferro-Alloys

Committee A-9 held its first meeting since the close of the war, with secretary A. P. Spooner, of The Bethlehem Steel Co. presiding as acting chairman. All of the standards for ferro-alloys under its jurisdiction were reviewed.

These cover spiegeleisen (A 98), ferromanganese (A 99), ferrosilicon (A 100), ferrochromium (A 101), ferrovanadium (A 102), ferromolybdenum (A 132), ferrotungsten (A 144), and molybdenum salts and compounds (A 146).

Each of the specifications was reaffirmed without change except for the Specification for Molybdenum Salts and Compounds which will be revised during the coming year. The committee also decided to write new specifications for ferrotitanium and ferroboron. W. C. Bowden, Jr., of Ledoux and Company, was elected chairman, C. M. Loeb, Jr., of Climax Molybdenum Co., was reelected vice-chairman, and G. F. Comstock, of the Titanium Alloy Manufacturing Co., was elected secretary for the two-year period from 1948 to 1950.

Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys

One of the interesting and significant matters discussed during the meetings of Committee A-10 was the progress reported in preparing the handbook of data on cast and wrought corrosion-resistant steels. A compilation on the wrought alloys was issued by the Society in 1942 and widely distributed. Meanwhile the committee has been compiling data on cast alloys and bringing that on the wrought materials up to date. Publication is expected late this year.

Aside from specification matters in the committee, it was reported that the Subcommittee on Corrosion Testing will be ready to begin exposure tests on stainless materials as soon as sites and racks are made available. Mechanical testing of austenitic steels is being given further consideration aimed at more precisely defining testing methods on such materials. Metallographic methods for detecting the sigma phase are being studied in an extensive series of aging tests, impact tests and examination on three steels of austenitic type, two of which contain molybdenum. X-ray diffraction and various etching reagents will be used by cooperating laboratories.

Advisory Committee on Corrosion

For over forty years a number of committees of the American Society for Testing Materials have conducted atmospheric exposure tests at sites throughout this country and in the tropics, now numbering some twenty-six, to determine the effect of various atmospheres on metals, metal coatings, paints, etc. Within the past two years, authority for the acquisition and maintenance of such sites has been vested in the Advisory Committee on Corrosion. A program to establish some half dozen sites where security and length of tenure can be assured was one of the main topics discussed by the committee, of which C. D. Hocker of Union College, Schenectady, is chairman. The committee has selected the smaller number of sites as being representative of conditions useful for test purposes for most of the committees of the Society interested in atmospheric corrosion testing. The committee also discussed the need for fundamental basic research on the mechanism of stress corrosion.

(The statement of Committee B-1 on Wires for Electrical Conductors, will appear in the May issue.)

Committee B-2 on Non-Ferrous Metals and Alloys

While Committee B-2 did not have a meeting of its main group in Washington during A.S.T.M. Committee Week, its Advisory Committee and several subcommittees met on March 3 and 4.

The committee noted with deep regret the severance from active association with its work of William B. Price who has retired recently as Director of Research of the Scovill Manufacturing Co. Mr. Price had long been associated with the work of Committee B-2 and his advice and counsel will be missed.

Progress was reported on the proposed new Specification for Antimony which should be in final form by the June meeting. It was decided to include only two classes in this—one with a minimum of 99.8 per cent antimony and the other with a minimum of 99.5. Marshall Tuthill, of New York, presented an analysis of the present tin situation which was discussed at some length. His presentation was favorably commented upon. It was decided that while the present tin situation exists, it is not practical to write A.S.T.M. Specifications for Tin.

The Subcommittee on White Metal Alloys received a report from a task group recommending minor changes in the Specification for Babbitt (B 23) and for Solder (B 32) which was approved for reference to letter-ballot. The subcommittee also voted to table for the present a proposal to write specifications for fusible alloys.

Another subcommittee considered at some length proposed revisions in the Specification for Lead-Coated Copper Sheets (B 101) and referred to a task group the problem of working out acceptable details for the revisions.

Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys

Committee B-3 reviewed the work of some of its subcommittees. The Subcommittee on Total Immersion Corrosion Tests has formulated its plans to make some cooperative tests. The Subcommittee on Spray Test discussed some refinements in the Method of Salt Spray (Fog) Testing (B 117) and recommended the sponsoring of a paper on apparatus and factors in such testing.

The Subcommittee on Humidity Tests will enlarge its membership to include representatives of other A.S.T.M. main technical committees interested in humidity tests and will write up a method of humidity testing applicable to all types of materials. The Subcommittee on Atmospheric Tests reported that the Joint B-3–B-7 Committee on Atmospheric Tests of Magnesium Alloys had outlined a test plan which was now being considered by the members of Committee B-7.

The Subcommittee on Weather has appointed a subgroup to study available instruments for the measurement of air pollution. This subcommittee also plans to expose specimens of zinc and iron at the several A.S.T.M. exposure test sites in order to obtain data on the corrosivity of each site.

The Subcommittee on Galvanic and Electrolytic Corrosion will submit data on a five-year test of stainless steels coupled with other metals exposed to outdoor weather. Its program for exposing magnesium alloys coupled to other metals in outdoor atmosphere is progressing, and a large number of assemblies will be exposed this summer.

Committee B-4 on Electrical Heating, Resistance and Related Alloys

Prior to A.S.T.M. Committee Week, Committee B-4 held a meeting at the Society Headquarters in Philadelphia on February 11 and 12.

The Subcommittee on Electrical Heating Materials is making a check test to determine the importance of voltage regulation in the Method for Accelerated Life Test for Metallic Materials for Electrical Heating (B 76).

The Subcommittee on Electrical Tests has just completed an extensive review and revision of the Method of Test for Resistivity of Metallic Materials (B 63). A cantilever method for determination of elastic modulus and yield strength of thermostat metals has just been completed and a hardness testing procedure for thermostat metals is being developed.

The Subcommittee on Metallic Materials for Radio Tubes, of which S. A. Standing of Tung-Sol Lamp Works, Inc., is chairman, and its Section A on Cathode, of which T. H. Briggs of Superior Tube Co. is chairman, reported further progress in their very important study of the emissivity of cathode nickel. Experimental melts of nickel with controlled additions of potential impurities are now ready for testing. A spectrochemical method for analysis of cathode nickel has been completed and a chemical method is being prepared. A method of test for particle size has also been finished and referred to the main committee for approval.

The Subcommittee on Tests of Alloys in Controlled Atmospheres continues its study of the phenomenon of "green rot." The Subcommittee on Contact Materials has cooperated with the Subcommittee on Electric Tests in preparing a section of the resistivity method applicable to powder metallurgy products. A 1947 addendum to the Bibliography on Electrical Contacts has been completed and will soon be ready for publication.

Committee B-5 on Copper and Copper Alloys Cast and Wrought

At the three-day meetings of Committee B-5, the subcommittees on wrought products voted to recommend the adoption of up-to-date Copper & Brass Research Association size tolerances in the sheet, rod, and wire specifications, and also to apply to their specifications the new Tentative Classification of Copper (B 224). A study is being made of the tin limits in the phosphor bronze specifications (B 103, B 139, and B 159).

The Subcommittee on Plate, Sheet, and Strip is recommending minor changes in the Specifications for Copper-Nickel-Zinc (B 122), Phosphor Bronze (B 103), and Copper (B 152) Plate, Sheet, and Strip. The subcommittee continues its study of the relation of hardness to tensile strength of beryllium copper strip, the requirements for aluminum bronze sheet, and the addition of sawed bars to its plate specifications.

The Subcommittee on Rods, Bars, and Shapes is recommending the application of the recently written Method of Tension Testing of Copper and Copper Alloy Rod (B 220) to its specifications and the deletion of the bend test in six rod specifications (B 16, B 21, B 98, B 138, B 139, and B 150). The need for the inclusion of additional rectangular sizes in the two specifications for copper rod (B 133 and B 187) is being studied.

The Subcommittee on Wire and Wire Rod is studying the substitution of grain size limits for strength requirements in the Specification for Phosphor Bronze Wire (B 159). The Subcommittee on Pipe and Tube is recommending minor revisions in the hydrostatic and pneumatic test requirements in the copper tube and condenser tube specifications (B 75, B 88, and B 111) and the deletion of weight tolerances from several of them. Minor changes in chemistry and revision of size tolerances are also recommended in the Specification for Condenser Tubes (B 111). The subcommittee continues its study of new requirements for copper tube for automotive and refrigeration use and the addition of new temper requirements.

The Subcommittee on Castings and Ingots received a report from the recently organized Test Bar Task Group reporting progress in the initiation of this important project. It also recommended the publication in the ASTM Bulletin of a paper by Professor Allison Butts of Lehigh University dealing with the effect of iron impurity on the magnetic properties of copper-base alloys. The subcommittee also is recommending minor changes in chemical requirements in both casting and ingot specifications for six alloys (2B, 3A, 3D, 3E, 8B, and 8C) and in physical requirements for one (8B). A new sampling procedure is to be incorporated in the Specification for Phosphor Copper (B 52).

The Subcommittee on Methods of Test is recommending some revisions in the Method for Tension Testing of Copper Alloy Rods (B 220) and new methods of tension testing of thin sheet (from 0.002 to 0.010 in. thick) and the ultimate incorporation of both requirements in the general methods of Tension Testing of Metallic Materials (E 8). The subcommittee continues its study of the Rockwell Hardness Test with reference to the limitations imposed by the thickness of the specimen and also its study of the effect of speed in the tension testing of copper alloys.

The Subcommittee on Editorials and Publications is completing a review of the chemical limits of all of the Committee B-5 wrought product specifications and is making a study of alloy nomenclature and designation as well as preparing a history of the committee.

Committee B-6 on Die-Cast Metals and Alloys

Action on several standards was taken in subcommittee meetings and confirmed at the main committee meeting of Committee B-6. These included changes in the chemical composition of Alloy XXIII in the Specification for Zinc-Base Alloy Die Casting and removal of the material relating to the mechanical properties of the three alloys in this specification (B 86) to the appendix. A new Specification for Alloy Ingot for Zinc-Base Alloy Die Castings was proposed and will be submitted to letter ballot.

The specification for Aluminum-Base Alloy Die Castings (B 85) will be continued as tentative and a new alloy of 8.0 per cent nominal magnesium content added. One of the alloys in the magnesium-base alloy die casting specifications (B 94) has been deleted and a third alloy has been added to the Specification for Copper-Base Alloy Die Castings (B 176). This alloy will have a nominal composition of 82.0 per cent copper, 4.0 per cent silicon, zinc remainder.

Committee B-7 on Light Metals and Alloys, Cast and Wrought

In the Specification for Aluminum and Aluminum Alloy, Sheet and Plate (B 209), Committee B-7 on Light Metals and Alloys voted to delete the ZG43 alloy (nominal 6.0 zinc, 2.5 magnesium, 1.3 copper) and the Clad ZG43 because these materials are no longer commercially available. In the same specification it was voted to revise Table II by including, for each alloy, requirements for plate up to the present maximum commercial thickness (some alloys are available in thicknesses greater than the table now covers). It was also proposed to add a new alloy to this same specification and this subject was assigned to a task group for further study.

In the specifications for rods, bars and shapes for magnesium (B 107) and for aluminum (B 221) it was voted to make revisions in Table III of each covering permissible variations in cross-sectional dimensions to bring these tables up to date. In the Specification for Magnesium-Base Alloy Extruded Round Tubing (B 217) it was voted to amend Table II to include tensile requirements for tubes with wall thicknesses of 0.050 to 0.500 in. in place of the present upper limit of 0.250 in.

A preliminary program was presented for a corrosion study covering a number of typical aluminum and magnesium alloys exposed at five different locations—marine, industrial, and rural—distributed across this country and in the tropics.

(*Continued on page 23*)

Actions on Steel, Rubber, and other Standards

In February and March the Administrative Committee on Standards accepted a number of important recommendations from several technical committees including A-1 on Steel and D-11 on Rubber and Rubber-Like Materials these actions being noted in the accompanying table. All of the new and revised steel specifications appear in the 1947 Supplement to Part I-A of the Book of Standards; the recommendations from Committee D-11, including the new tentative on rubber, do *not* appear in Part III-B Supplement, but do appear in the latest edition of the Compilation of Standards on Rubber Products, dated February, 1948. Notes on some of the actions listed in the accompanying table appear below.

All of these actions are taken by the Administrative Committee on Standards in accordance with the regulations of the Society, which provide that this committee shall determine whether the technical committees have reached a consensus on their specific recommendations, and then has the authority to act for the Society in approving the publication of such items. This Administrative Committee can approve new tentatives, revisions of existing tentatives, and proposed revisions of formal standards, which revisions are published usually for a year or more before adoption.

Steel:

The new Specification for Seamless 1 per cent Chromium-0.5 per cent Molybdenum Alloy-Steel Pipe for Service at High Temperatures (A 315) is intended to provide a grade of pipe now in growing use which will give further reassurance against graphitization. When this phenomenon was discovered a few years ago, a considerable amount of research was carried out, and this led to the establishment of Specification A 280 covering ½ per cent chromium-½ per cent molybdenum alloy steel. The piping industry believes another grade with higher chromium is desirable as added reassurance. Whether the proposed new specifications will supersede A 280 is a moot question, and if not, it may be that in two or three years the specifications can be combined, but the new requirements were agreed to on the basis of a separate, distinct specification.

The other new specification developed in the Steel Committee covering Stress-Relief Annealed Cold-Drawn Carbon-Steel Bars (A 311) covers material suitable for applications where high strength, good machinability, and a minimum of distortion are important. Certain grades particularly applicable for the process covered are noted and it is pointed out that grades other than these can be stress-relief annealed with beneficial effect. The table of mechanical properties indicates that, depending upon size and grade, ranges of minimum tensile strength can be obtained from 90,000 to 105,000 psi., with yield strengths of 75,000 to 85,000 minimum psi.

The proposed changes in the widely used standard for structural steel, A 7 would eventually incorporate requirements on speed of testing, and there is some other editorial rearrangement. However, as indicated elsewhere in this Bulletin a major study is under way involving this and other structural steel specifications.

The two tentative specifications for castings for high-temperature service, A 216 (Carbon) and A 217 (Alloy) are modified by the addition of a paragraph on radiographic or destruction tests; and A 217 has major additions involving five new grades of material, two of which are chromium-molybdenum chemistry, one a nickel-chromium-molybdenum, still another of the molybdenum-vanadium family, and the fifth a carbon-molybdenum.

The tentative revision of the standard flange specification A 182 was intended to provide a new grade of 1 per cent chromium-0.5 per cent molybdenum, but the Steel Committee is reverting this complete specification to tentative, and will incorporate this grade and other changes. Action is expected later in the spring or at the annual meeting.

The high-temperature pipe specifications A 158 (Alloy-Steel), A 206 (Carbon-Molybdenum), and A 280 (Chromium-Molybdenum) have been clarified through changes in reference to the words "lot," "heat number," etc., and additional requirements are

Actions by the A.S.T.M. Administrative Committee on Standards, February and March, 1948

New Tentatives

Specifications for:

Stress-Relief Annealed Cold-drawn Carbon-Steel Bars (A 311–47 T).
Seamless 1 Per Cent Chromium, 0.5 Per Cent Molybdenum Alloy-Steel Pipe for Service at High Temperatures (A 315–47 T).

Methods of:

Test for Mechanical Properties of Elastomeric Vulcanizates Under Compressive or Shear Strains by the Mechanical Oscillograph (D 945–48 T).
Photometric Method for the Determination of Boron in Steel (E 30–48 T).

Classification of:

Copper (B 224–48 T).

Tentative Revisions of Standards

Specifications for:

Steel for Bridges and Buildings (A 7–46).
Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-temperature Service (A 182–46).

Method of:

Test for Indentation of Rubber by Means of the Pusey and Jones Plastometer (D 531–41).

Revision of Standard and Reversion to Tentative

Specifications for:

Carbon-Steel Axles for Cars and Tenders (A 21–47 T).

Revision of Tentatives

Specifications for:

Carbon-Steel Blooms, Billets, and Slabs for Forgings (A 273–47 T).
Carbon-Steel Castings Suitable for Fusion Welding for High-Temperature Service (A 216–47 T).
Alloy-Steel Castings Suitable for Fusion Welding for High-Temperature Service (A 217–47 T).
Seamless Alloy-Steel Pipe for High-Temperature Service (A 158–47 T).
Seamless Carbon-Molybdenum Alloy-Steel Pipe for High-Temperature Service (A 206–47 T).
Seamless Chromium-Molybdenum Alloy-Steel Pipe for Service at High Temperature (A 280–47 T).
Rubber and Synthetic Rubber Compounds for Automotive and Aeronautical Applications (D 735–48 T).

Methods of:

Testing Hard Rubber Products (D 530–48 T).
Testing Automotive Hydraulic Brake Hose (D 571–48 T).
Impact Testing of Metallic Materials (E 23–47 T).

Withdrawal of Tentative

Specifications for:

GR-S (Synthetic Rubber) Sheath Compound for Electrical Insulated Cords and Cables Where Extreme Abrasion Resistance Is Not Required (D 812–44 T).

incorporated on the number of tests.

Boron in Steel:

The importance of a standardized and satisfactory method for determining boron in steel led Committee E-3 on Chemical Analysis of Metals which is responsible for the Methods of Chemical Analysis of Iron and Steel (E 30 – 48 T) to investigate the various methods used. Cooperative tests were carried out in the committee and the proposed method now accepted for publication as tentative proved to be reasonably rapid and accurate. While the method is essentially a tentative revision of the Standard E 30, it will be issued in separate pamphlet form and a copy will be furnished each A.S.T.M. member on request. Additional copies can be procured by purchase.

Impact Testing of Metals:

The revisions being incorporated in the Tentative Methods of Impact Testing of Metallic Materials (E 23 – 47 T) resulted from use of the method during the war period and comments received since the last revision in 1941. Explanatory material is incorporated in the sections on scope and significance. It is pointed out that the significance of the Charpy and Izod type tests is to bring out notch behavior (brittleness *versus* ductility) by applying a single overload of stress. This revised method was published in the 1947 Supplements to the Book of Standards in both Parts I-A and I-B, Ferrous and Non-Ferrous Metals, respectively, and is available in separate pamphlet form.

Classification of Copper:

After lengthy discussion and very careful consideration of a classification of copper, which project was assigned to a joint committee consisting of representatives of Committees B-1 on Wires for Electrical Conductors, B-2 on Non-Ferrous Metals and Alloys, and B-5 on Copper and Copper Alloys, Cast and Wrought, the Tentative Classification of Copper (B 224) was agreed on. This covers various types of copper currently available in refinery shapes and wrought products. The table giving the classification, names the types of copper, with designations—for example, Fire-Refined Tough Pitch, FRTP, and then data are given on the various forms in which this particular type is available. Some seventeen copper types are listed, and accompanying the classification is a condensed definition of terms used. This particular item does not appear in the 1947 Supplement, Part I-B, but is available in separate pamphlet form. A.S.T.M. members who wish a copy of this can obtain one on request, without charge. It will be published in the 1948 Book of Standards Supplement, and later in the Committee B-5 Compilation.

Rubber Products.

The new Test for Mechanical Properties of Elastomeric Vulcanizates under Compressive or Shear Strains by Means of the Yerzley Oscillograph (D 945) has been quite widely used in the study of rubber used for vibration damping as in motor mounts, springs, etc. The method has not previously been available in standardized form. It is desired by many of the automotive interests and has been developed and recommended by D-11 Subcommittee XXVII on Resilience Tests. The Scope clause reads as follows:

> These methods describe the use of the Yerzley Oscillograph for measuring the mechanical properties of elastomeric vulcanizates, which are important in the engineering of these materials, for the absorption and isolation of vibration. These properties are: resilience, dynamic modulus, static modulus under slow or practically static conditions, kinetic energy, creep, and set under a given dead load. Measurements in either compression or shear may be made. In applying data obtained from a compression specimen, the shape factor of the test specimen must be taken into consideration (shape factor is the ratio of the loaded area to the unloaded surface area). It is important to emphasize that the dynamic modulus, when obtained under conditions of strain which exceed the straight line portion of the load-deformation curve, is not an actual physical modulus and is, therefore, called "Effective Dynamic Modulus." No significant test can be made on materials (plastics, hard rubber, high durometer vulcanizates, etc.) whose moduli, at temperature of test, are such that a load of 280 psi. in compression or 140 psi. in shear (on standard test specimens) will not produce at least 10 per cent deformation and/or whose damping characteristics are such that less than three full cycles are produced when obtaining the damped sinusoidal curve.

The withdrawal of the Specification for GR-S Sheath Compound (D 812) is justified because it was essentially a war product. The change in the Pusey and Jones indentation Test Method (D 531) extends its scope to very soft rubber compounds by providing for a larger indentor. Revisions in the tests for Hard Rubber Products (D 530) and Automotive Rubber Compounds (D 735) essentially are clarifications and improvements. The modified procedures for testing automotive hydraulic brake hose (D 571) incorporate the use of a salt spray test for evaluating the couplings and provide for the testing of longer lengths of brake hose. These methods are considered very important in a somewhat limited field.

Publication Notes

THE publication schedule of the Society is a full one and we are pleased to announce the availability of several new publications as well as the release for press of several others. All of the supplements to the 1946 Book of A.S.T.M. Standards are now available, Parts I-A and III-A having just recently been issued.

Everyone will be interested to know that the 1947 *Proceedings* are on press and copies should be available soon. These *Proceedings* contain all the technical papers and committee reports presented at the 1947 annual meeting, together with the very valuable discussions. The book aggregates 1200 pages.

Standards and Related Publications:

The compilation sponsored by Committee D-11 on Rubber and Rubber-Like Materials has just become available. Comprising 574 pages it includes 82 standards, 4 of which appear in the book for the first time and about 41 of which have been revised since the last printing in March of 1946. The standards are grouped under such headings as the following:

Processibility Tests
Chemical Test and Physical Tests of Vulcanized Rubber
Aging and Weathering Tests
Low Temperature Tests
Automotive and Aeronautical Rubber
Rubber Hose and Belting
Rubber Gloves, Matting, Tape
Rubber-Coated Fabrics
Insulated Wire and Cable
Hard Rubber and Cellular Rubber
Rubber Cements and Latices
Packing Materials
Nonrigid Plastics
Electrical Tests
Nomenclature and Definitions

Copies of this widely used publication can be procured by members at the special price of $3; the list price being $4.

Recently off press is the steel piping compilation sponsored by Committee A-1 on Steel. This is the

fifth edition of this book and it provides all those concerned with the production and use of steel piping materials with a handy up-to-date compilation of a great majority of the A.S.T.M. specifications of concern in the field of steel piping. The specifications are listed under such headings as:

Pipe
Boiler, Superheater, and Miscellaneous Tubes
Still Tubes
Heat-Exchanger and Condenser Tubes
Castings
Forgings and Welding Fittings
Bolding
Grain Size

Members can procure this 318-page publication at $2.25; list price $3.

Another publication which will be released for press very shortly is the A.S.T.M. Manual of Engine Test Methods for Rating Fuels. This manual, issued for the first time by the Society, presents in their latest approved form the five standard methods for rating motor, aviation, and Diesel engine fuels. There is a wealth of supplementary information concerning not only operation and maintenance details, but also building and utility requirements, installation and assembly of the engine, and reference fuels. The publication is profusely illustrated throughout. In addition to the many drawings and photographs, there are numerous tables and charts. Some of the tables, data sheets, and charts which appear in the manual are available separately in 8½ by 11-in. size. The price on these vary. The manual which covers approximately 325 pages is available to members in cloth binding at $6 per copy; list price $8.

A revised edition of Standards for Students in Engineering is also scheduled to come out within the next few weeks.

Special Technical Publication:

The publication Petroleum Products as Related to Automotive Equipment, Special Technical Publication No. 81, has just become available. This contains the two papers presented at a joint meeting of the Detroit District and Committee D-2 on Petroleum Products covering Petroleum Lubricating Oils as Related to Automotive Equipment by C. M. Larson, and The Efficient Production and Utilization of Motor Gasoline by W. M. Holaday. This publication comprises 52 pages and is available to members at 75 cents; list price $1.

Urgent Need for X-ray Diffraction Data Cards

THERE is urgent need for at least one original set of X-ray Diffraction Data Cards. If any purchaser has no further use for his original set of cards and would be interested in selling it, please advise Headquarters.

The X-ray Diffraction Data Cards were issued in two sets; an original set of 4000 cards and a "First Supplementary Set—1945" of 4500 cards. Our stock or original sets has been depleted for several weeks.

The Joint Committee of Chemical Analysis by X-ray Diffraction Methods, under whose jurisdiction these cards were developed, has been working on a plan to revise the format of the cards with the possibility of showing the four strongest lines on the data card for each compound or mineral and eliminating the two cross-reference cards. Also a suggested "punched index" system is being considered. The result is that it will be some time before any sets of cards are available.

Partial Bibliography on Effect of Speed of Testing Published

UNDER the sponsorship of the Section on Speed of Testing, a division of the Society's Committee E-1 on Methods of Testing, there has been prepared a rather extensive Bibliography on Effect of Speed of Testing on the Results of Physical Tests of Various Materials. This Bibliography of 51 mimeographed pages, 8½ by 11 in., can be procured as long as the supply lasts at $1 per set. There are some 265 references with many of them including short abstracts of the material covered. The first Bibliography on the subject was prepared in 1936 by R. L. Kenyon of American Rolling Mill Co. This was revised a few years later through the interest of Francis J. Tatnall, Baldwin Locomotive Works, and the current greatly extended revision was prepared by Messrs. B. L. Wilson, D. W. Quick, and J. R. Dwyer, of the National Bureau of Standards. Orders should be transmitted to A.S.T.M. Headquarters.

British International Plastics Annual

THE British International Plastics Annual represents an ambitious attempt to compile in one publication all the varied information on plastics most helpful to the actual users of plastics as engineering materials as distinguished from industrial chemists and physicists on the one hand and from the "man in the street" on the other. While the book contains some material of an advertising nature, it is primarily an encyclopedia of interesting and useful information. It should be a valuable reference book, its worth depending upon how accurate, up to date, and authoritative are the data and statements included. This book is made up of sections on the following subjects:

"Plastics" consisting of a discussion of the development of the plastics industry and of the terminology used in the industry (8 pages). The term "plasthetics" is suggested for the synthetic plastics to set them apart from other materials that are also plastics in the sense that they can be molded at some stage in fabrication.

"Chemistry of Synthetic Plastics" consisting of a discussion of the chemical composition and chemical behavior of plastics and very brief notes on the chemical analysis of plastics (116 pages).

"Properties of Synthetic Plastics" consisting of a discussion of accepted methods of test and their limitations (40 pages). Many A.S.T.M. Standards are discussed and compared with corresponding British Standards and other standard methods.

"Fabrication Processes" covering equipment and processes for the various methods of fabricating plastics (70 pages).

"Miscellaneous Applications of Plastics" (14 pages).

"Notes on Physical Tests" presenting simplified discussion of the principles of tests for pH value, refractive index, coefficient of thermal conductivity, and X-ray analysis (22 pages).

"Properties of Plastics" consisting of a tabulation for each of many plastics of some 54 significant characteristics (86 pages).

"Plant and Machinery" consisting chiefly of a tabulation of the characteristics of commercially available equipment used in the manufacture of plastics (12 pages). "100 Solvents and 100 Plasticizers" giving properties of these materials and names of manufacturers (10 pages). "Molders and Fabricators' Trade Marks" (8 pages). "Societies and Trade Associations" giving addresses, officers, and descriptions of groups concerned with the plastics industry in the United States and the British Empire (22 pages).

"Trade Names and Descriptions" giving trade names and brief descriptions of plastics and the names of certain manufacturers of them (18 pages). "Manufacturers Agents" (6 pages). "Educational Facilities" giving a list of institutions offering special training for the plastics industries (4 pages). "Trade Directory" (10 pages).

This publication, containing many helpful illustrations and exceptionally clearly printed on good paper, is available at 63 shillings per copy from Croome Hill International Ltd., 100 Victoria St., London, S.W., England.

Available separately at 30 shillings per copy is a limited issue of the "Directory Section" comprising that portion of the book which begins with the section on "Properties of Commercial Plastics."

ASTM Bulletin

MARCH 1948

NO. 151

NINETEEN-SIXTEEN
RACE STREET
PHILADELPHIA 3, PENNA.

Nominations for Officers

THE Nominating Committee to select nominees for Society officers met in Philadelphia on March 6. The personnel of this group was listed in the January BULLETIN. In accordance with the provisions of the By-laws of the Society the following nominations are announced:

For President (term 1 year):

Richard L. Templin, Assistant Director of Research and Chief Engineer of Tests, Aluminum Company of America, New Kensington, Pa.

For Vice-President (term 2 years):

L. J. Markwardt, Assistant Director, U. S. Forest Products Laboratory, Madison, Wis.

For Board of Directors (term 3 years):

Leslie C. Beard, Jr., Chemist, Socony-Vacuum Oil Co., Inc., New York, N. Y.

Simon Collier, Director of Quality, Johns-Manville Corp., New York, N. Y.

Theo. P. Dresser, Jr., Chief Engineer, Abbot A. Hanks, Inc., San Francisco, Calif.

Howard K. Nason, Assistant Director, Central Research Dept., Monsanto Chemical Co., Dayton, Ohio.

Edgar W. Fasig, General Superintendent, Lowe Brothers Company, Dayton, Ohio.

Each of the above nominees has indicated in writing his acceptance of his nomination. The By-laws provide that "further nominations, signed by at least 25 members, may be submitted to the Executive Secretary in writing by May 25, and a nomination so made, if accepted by the member nominated, shall be placed on the official ballot" which "shall be issued to members between May 25 and June 1."

Membership—a "Thank You" and a Request

IN OUR November communication to every A.S.T.M. member we pointed out that the Committee on Membership was *your* committee and we stressed the fact that the best asset the committee had was you, a member. The most productive source for new members down through the years has been the suggestions and interest of our members. Ample evidence of this situation was soon forthcoming in the large number of returns which you sent us giving the names of individuals and companies who should benefit from contact with the Society's standardization and research work in materials. Except in a few instances those communications have not been individually acknowledged, but the committee has gone right ahead following through with the excellent suggestions. Not only the Membership Committee, but the Board of Directors, of which it is an arm, greatly appreciates the interest which so many hundreds of you took.

The Society needs a continuing inflow of new companies and new members not only from the standpoint of the Society's support but of stimulating and maintaining a broadening interest in our work in materials. The Society is part of our whole broad plan of industrial activity, and the voluntary promulgation and acceptance of essential specifications and tests for materials are a part of our way of doing things. Not only the national but the world-wide recognition of A.S.T.M. standards is justification to us for the interest we are attempting to stimulate in membership growth.

We were quite successful in 1947 in procuring new members, within a very few of the high of 1946, but losses took a greater toll, and our net increase was only about 250. We hope to better that figure this year. Considering the broad diversity of A.S.T.M. work and its tremendous output of publications and standards, and all the other things the Society does, a membership of about 6400 scarcely seems the ultimate. And the figure is not a small one either because it includes a great body of leading companies and materials men who together make A.S.T.M. what it is.

Whenever there occurs to you the name of an individual or company who would benefit from A.S.T.M. and who might contribute to the advancement of our work, please advise the Membership Committee through Headquarters.

FOR THE MEMBERSHIP COMMITTEE
CARLTON H. ROSE, *Chairman*

Schedule of A.S.T.M. Meetings

DATE	GROUP	PLACE
April 9	St. Louis District (Research)	St. Louis, Mo.
April 12	Executive Committee	Philadelphia, Pa.
April 13	New York District (Meteorogical Engineering)	New York, N. Y.
April 14	New England District	Boston, Mass.
April 16	Administrative Committee on Research	Philadelphia, Pa.
April 26	Pittsburgh District (Post-War Japan through Metallurgists' Eyes)	Pittsburgh, Pa.
April 26, 27	Committee D-10 on Shipping Containers	Cleveland, Ohio
May 10, 11	Board of Directors	Philadelphia, Pa.
May 20	Western New York-Ontario District (Instruments and Testing in Europe)	Niagara Falls, Ont., Canada
June 21–25	1948 ANNUAL MEETING AND EXHIBIT OF TESTING APPARATUS	Detroit, Mich.

Financial Highlights—1947

1948 Budget

WHILE a detailed report of the financial operations of the Society during 1947 will be included as customary in the 1948 Annual Report of the Board of Directors, there are some interesting highlights which are excerpted below from the report submitted by the Executive Secretary to the Board at its January meeting. The report of the Board will be preprinted in advance of the annual meeting and distributed to all those who request preprints of papers or reports. Copies will be available at the annual meeting and it is urged that members procure the report for study and reference for it will represent a review of the Society's major operations (Distribution to those returning a preprint blank may not be possible until after the meeting but the report will be available in Detroit and it is, of course, published in full in the *Proceedings*.)

1947 Operating Receipts

The operating receipts for 1947 were $428,064. Of this amount $144,431 (33.7 per cent) came from dues and entrance fees, and $251,708 (58.8 per cent) from sales of publications. Receipts from all other sources were $31,925 (7.5 per cent), of which $17,046 was from advertising, $6968 from interest and dividends, and $5054 from registration fees at meetings.

Of the income from publications, $96,524 came from sales of the 1946 Book of Standards. Another large item in sales of standards is the $44,637 realized from the distribution of special compilations of standards. The income from special and miscellaneous publications reached the total of $40,626. Including the charge to members for procuring extra parts of the Book of Standards, the total income for the year directly attributable to standardization work is about $202,115.

A reference to the accompanying Income Dollar chart will show that the sales of publications are a most important part of the income, exceeding that from dues by a very substantial amount.

1947 Operating Disbursements

In the 1947 budget it had been estimated that operating disbursements would exceed receipts by about $5000, and the budget was not far off, with the deficit actually being $2333, the total operating disbursements being $430,397. This figure is the highest it has ever reached. The increased pace of the Society's operations, resulting in a very heavy publication schedule, necessary additions to the staff, and particularly higher printing costs, was responsible for it. The principal budget subdivisions and disbursements, and the amount spent in each, are approximately as follows: publications, $195,617; salaries $144,601; general office expenses, $33,925; expenses for meetings and for technical and district committees, $21,545; headquarters occupancy expenses (equivalent to rent), $14,013; miscellaneous, $20,696, including $9322.57 as the Society's contribution to the A.S.T.M. Retirement Fund for Employees.

It might be noted that the disbursements for publications of about $196,000 included $20,000 set aside from income as a reserve for the next edition of the Book of Standards. This is in line with the methods of financing the triennial publication of this big book.

It might also be noted that while the disbursements for salaries is the highest in history, accounted for substantially because of four additions to the stenographic staff and general salary increases at the beginning of the year, the percentage ratio of salary disbursements to total is the lowest for some years.

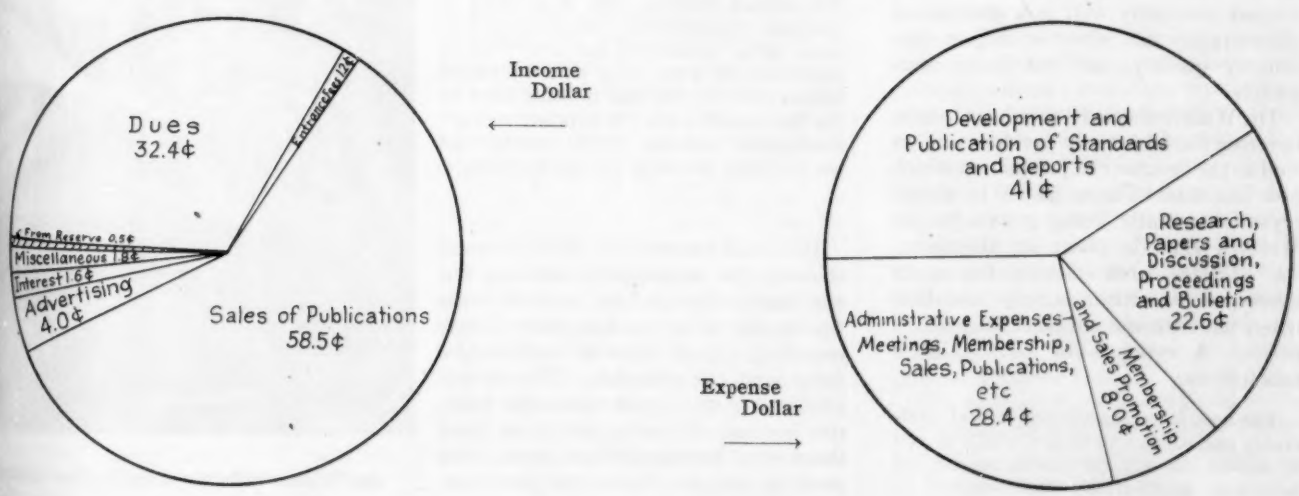
Surplus

While there was an operating deficit of over $2000, this is on a cash basis, and the net surplus actually increased, to a figure of $157,418, compared with the 1946 figure of $144,210. This is due primarily to a greatly improved position in accounts receivable compared to the accounts payable. Nevertheless the percentage ratio of surplus to disbursements *decreased* sharply and is now about 37 per cent compared with the high of 60 per cent in 1945. In other words, our present surplus is a little over a third of annual operating expenses.

1948 Budget

In preparing the budget for 1948, the Board of Directors has estimated current operating receipts at $464,000, of which it is expected that about $200,000 will come from membership dues and entrance fees, $221,000 from sales of publications, and $43,000 from miscellaneous sources, which include advertising in the ASTM Bulletin, interest and dividents, registration fees, the 1948 A.S.T.M. Exhibit, and other sources.

The figure for dues income, is, of course, considerably higher than for any other year, largely because of the increased dues which went into effect on January 1 of this year. Members were fully advised of the deliberations which led to these increased dues and the fact that they were approved at the annual meeting for submission to letter ballot, and subsequently by letter-ballot vote of the membership. It is gratifying to report that, by and large, the company and sustaining members, where the increase was largest, are continuing



their support of the Society's work, and while there are a few transfers which may be attributable to the higher dues, the Board is gratified with the continuing support of A.S.T.M. work by Society members and by industry generally.

The figure of $221,000 for sales of publications is subject to a number of variables but the operations for the first quarter of the year are encouraging and would indicate that the budget figure is a fair one. A most important part of this total is the income expected from the several special compilations of standards, which thus not only augment the Society's income but are most effective in increasing distribution of standards and promoting their use.

Estimated Disbursements:

Total disbursements for 1948 are estimated at $437,000, of which $174,000 would be for publications and $154,000 for salaries, with other items in line with the estimated cost of general office expense, technical, district and related meetings, headquarters occupancy expense, etc.

The Finance Committee of the Society reviews the receipts and disbursements periodically throughout the year, the next review being at the May meeting, and will make any necessary modifications in the budget as may seem required by the trend of financial operations.

It might be noted in connection with the Finance Committee's 1948 budget that it is based on a definitely balanced budget with no "deficit financing" to be done, and, secondly, a maintenance of the Society's operations at least at present level.

ACTIVITY

While the financial operations of an organization are not necessarily a correct criterion of activity, the following figures may be significant; at least they show the growth in A.S.T.M. fiscal matters.

	Receipts	Disbursements
1935	$120,357	$119,994
1940	188,879	164,623
1945	324,065	277,191
1947	428,064	430,397

DISTRICT NOTES

New York Meeting on Research and Man-Made Crystals for Telephone Uses

ONE OF the most interesting meetings yet held by the New York District took place on February 17 when Past-President J. R. Townsend, Materials Engineer, Bell Telephone Laboratories, spoke on the general subject of Research in Action and Dr. A. C. Walker of the Laboratories covered the development of piezoelectric crystals which are essential for telephone and communication purposes. While Dr. Walker's subject was somewhat special, it was so presented by means of a very excellent colored film taken by one of the laboratory amateur photographers, Mr. J. J. Harley, that everyone in the audience seemed intently interested. The film was accompanied with a sound track lecture sequence given by Dr. Walker. Strictly aside from the excellent photography, the film demonstrated unusually well how the use of photography can cover a subject reasonably quickly, and yet quite completely.

Dr. Walker showed a number of slides covering the laboratory development, as well as the commercial production which now has reached from 30,000 to 40,000 crystals annually being grown in the Western Electric plant in Allentown, Pa. The research scientist has again overcome a critical supply situation where nature could not serve fully man's needs. A synopsis of Dr. Walker's talk follows.

The need for a piezoelectric crystal, preferably one which can be artificially grown to relieve the critical quartz supply for telephone applications, has resulted in the development by the Bell Telephone Laboratories of a new organic crystal made from ethylenediamine tartrate. Some recent improvements in methods of growing synthetic crystals were described and a general discussion was given of some of the problems requiring solution in the art of growing large single crystals.

Two general methods of growing such crystals have been employed: (1) by the gradual reduction of temperature of a solution containing suitable seeds and saturated at elevated temperature, and (2) by feeding a solution saturated at one temperature into a tank containing seed crystals kept at a constant temperature slightly lower. In each, growth depends upon supplying salt to the growing faces uniformly and is accomplished by careful control of the degree of supersaturation and also the circulation of the supersaturated solution around the growing crystal. The second method, that of growing at constant temperature, was described in some detail because it has now been in operation for some time as a successful commercial process, and is being used by the Western Electric Co. to produce ethylenediamine tartrate (EDT) crystals for use in voice filters in telephone circuits.

In his talk on research, Mr. Townsend stressed the relationship between the engineer on the one hand and the scientist on the other—the engineer always requiring a great store of fundamental data from the scientist. The current situation is at a point where the scientist instead of having ready at hand the store of knowledge that the engineer needs as was the case a few years ago now is being pressed for information. He cited the tremendous expenditures which the Federal Government made in 1947 of about $1,100,000,000 compared with a figure of about $100,000,000 in 1930, and approximately three times the latter amount in 1940. Even so, it is difficult to fill all of the various demands for basic information and data. Mr. Townsend referred to A.S.T.M. activities, mentioning the recent change in emphasis to composites and combinations of materials. He indicated that A.S.T.M. was attempting to meet the need for data on properties not only

Dr. Walker with "Crystals for Conversation"

of simple materials, but materials working together, supplementing each other. He mentioned some fields which are tied in with the development of scientific data in which work is needed along standardization and certainly research lines, the mass spectrograph being cited, infrared spectroscopy, etc. Aside from the critical nature of the problem and the absolute necessity of continuing an outpouring of authoritative data, he mentioned the pleasure and satisfaction which can come from producing what is needed and translating the data we have into a very practical use. The development of man-made crystals in the laboratory was cited as a project which should give tremendous satisfaction to those concerned. The job was well done, the results were gratifying, and the discussion of it was made much more interesting through the use of photographic presentation.

Myron Park Davis, Chairman of the New York District Council, presided at the meeting.

Preceding the technical talks, Assistant Secretary Painter extended greetings from the Board of Directors and the Staff, and mentioned that one of the ingredients in the outstanding success A.S.T.M. had made in its specific fields of standardization and research in materials, is the willingness of the members and committee members, from Past-Presidents on down, to take hold of a job where there was a definite aim and need evident, and carry through. He mentioned a statement by Dr. Jewett, formerly President of Bell Telephone Laboratories, that generally when as many as possible of the facts bearing on a particular problem can be determined and evaluated, the answer to a problem is usually about 90 per cent self-evident. This search for facts in connection with materials is one of the important responsibilities of the A.S.T.M. technical committees.

Pittsburgh District Honors J. J. Shuman

BECAUSE of his long and sustained interest in the activities of the Pittsburgh District, the Council at a recent meeting unanimously elected J. J. Shuman to Honorary Life Membership on the Council. For a great many years Chief Inspecting Engineer, Jones and Laughlin Steel Corp., Jesse, as he was widely known in A.S.T.M. and in steel circles, has been convalescing for some months from a severe stroke he suffered last year. Active in A.S.T.M. work for over four decades, he was elected an Honorary Member of the Society in 1946.

District Meetings Scheduled in Cleveland, St. Louis, New York, Boston, Pittsburgh, Ontario

FROM the accompanying Calendar of A.S.T.M. Meetings it will be noted that several A.S.T.M. Districts have meetings scheduled, and cordial invitations are extended to A.S.T.M. members and all interested, to attend. President Boyd, now fully recovered from his accident and illness, will on his return from district meetings in Southern and Northern California speak at several meetings in the East.

Dr. Carl Prutton, Head of the Chemistry and Chemical Engineering Departments at Case Institute of Technology, and a leader in research work, will join Mr. Boyd in Cleveland on April 7. Mr. Boyd is speaking on the general subject "Research—Everybody's Doing It Now" and Dr. Prutton will follow with "The Value of Research to Industry." Going on to St. Louis, Mr. Boyd will be joined by F. J. Curtis, Vice-President of Monsanto Chemical Co. on April 9.

Following a meeting of the Executive Committee at Headquarters on April 12, Mr. Boyd will be present at the meeting in New York to extend greetings, and then will speak the following night in Boston on April 14, where at Northeastern University Professor Albert Dietz of M.I.T., and A. L. Shields, of Westinghouse Electric in Springfield, will join him in the program, discussing phases of the subject "Solving Problems in Materials."

The Pittsburgh District has a most interesting program in store for its meeting on Monday, April 26, with talks by two men who have recently returned from Japan as part of an extensive industrial survey there. The general topic is "Japan Through the Eyes of a Metallurgist." E. T. Barron, formerly Chief Metallurgical Engineer, Carnegie-Illinois Steel Corp., and long-time A.S.T.M. member, will cover phases of ferrous metals; and W. W. Wentz, Metallurgist, Pittsburgh Central Metallurgical Dept. of the Aluminum Company of America, will cover non-ferrous metals.

The next meeting, on May 20, is under the auspices of the Western New York-Ontario section, to be held in Niagara Falls, Ontario, and is a joint meeting with a branch of the Engineering Institute of Canada. Chester H. Gibbons,* of the Baldwin-Southwark Corp., who has made an extensive trip in Europe studying testing and research in materials, and who visited some of the leading manufacturers of instruments and apparatus there, will discuss the high points of his trip and also draw on his extensive experience and knowledge in this field.

Full details of these meetings will be mailed to all members in the respective districts.

* Just as this BULLETIN goes to press, we are advised of the sudden death of Mr. Gibbons.—Ed.

New Washington (D. C.) District Officers Elected

AN ANNOUNCEMENT of the formation of a new A.S.T.M. district centering in Washington (D. C.) appeared in the January BULLETIN on page 11, with the list of nominees for district officers and councilors. This slate has been duly elected as a result of a letter ballot circulated to all A.S.T.M. members and committee members in the area covered, which includes most of Maryland and Virginia, except for the eastern shore, all of North Carolina and District of Columbia, and parts of West Virginia. There is a fairly heavy concentration of A.S.T.M. men in Washington, Baltimore, and other industrial areas in this district.

The new district council is headed by H. F. Clemmer, Engineer of Materials, District of Columbia, and the secretary is T. I. Coe, Technical Secretary, American Institute of Architects. The councilors include other active A.S.T.M. members. This group will plan a schedule of activities for the coming year and further announcements will be made.

Election of District Officers

EACH A.S.T.M. district council has already appointed or is in the process of appointing a nominating committee of five members to select nominees for officers and councilors to serve for the ensuing two-year term. Each nominating group consists of two members of the current council, plus three other A.S.T.M. members or committee members who are not on the council. Usually the immediate past district chairman heads the nominating committee. This slate of officers will be referred to the entire membership of the respective districts for letter ballot action in May, the ballot providing the opportunity of writing in additional names for councilors. This method of electing councilors was first inaugurated last year, and this year there will be some improvement in the mechanics and it is believed, will continue each year now on a routine basis.

The method of nominating and electing councilors is in line with the policy of having a greater degree of autonomy in the individual districts.

New Ohio Valley District Organizes—Meeting in Dayton on Research

At a meeting in Dayton, Ohio, on February 26, the newly appointed Ohio Valley District Council organized, and following this meeting the Council sponsored at the Dayton Engineers Club a most interesting dinner and district meeting on the subject of research, featuring an address by President T. A. Boyd, with interesting talks following by Messrs. J. M. Purdy, The Lowe Brothers Co., and Howard K. Nason, Monsanto Chemical Co., and Robert Burns, Bell Telephone Laboratories. Some notes on the new district and on the council meeting follow.

New Ohio Valley District

With the organization of the Washington (D. C.) District as noted elsewhere in this Bulletin, it was evident to the A.S.T.M. Administrative Committee on District Activities, which is responsible to the Board of Directors for the coordination and stimulation of district affairs, that the only gap remaining in the district map east of the Mississippi and excluding the deep south was the area centering in Cincinnati-Louisville-Indianapolis-Dayton. As a result of this consideration and with suggestions from members in that area that a district be formed, preliminary discussions were had with an interested group of members which led to the appointment by the Board of Directors of a council *pro tem*. This temporary group, the personnel of which is noted on this page, met in Dayton on the afternoon of February 26 under the chairmanship of John Bolton, of The Lunkenheimer Co., a long-time and active A.S.T.M. member, and proceeded to appoint a nominating committee to select a slate of officers and councilors for the new district, reviewed the area to be covered, and considered a program and plans for the district. The council also reviewed comments and replies from a questionnaire which had been sent to all A.S.T.M. members and committee members in the projected area.

Technical Meeting on Research

Through the good offices of Howard K. Nason, Assistant Director of Development, Monsanto Chemical Co. located in Dayton, a dinner was arranged at the Dayton Engineers Club, and following this the technical session was held.

Throughout the week technical committees D-9 on Electrical Insulting Materials and D-20 on Plastics had been meeting in Dayton, and there was an excellent turnout from these committees for the dinner and meeting. There were about 100 present at the dinner and upwards of 135 during the session.

Administrative Chairman C. H. Fellows presided at the session because of the inability of District Chairman John Bolton to stay for the session, although he had presided at the council meeting earlier.

Mr. Fellows described briefly the function of A.S.T.M. districts and complimented the Ohio Valley group on going right ahead with their organization. He then introduced President Boyd who spoke on "Research—Everybody's Doing It Now." It is planned that this paper will be published in the Bulletin, so no details are given here other than to record the fact that it was a most interesting presentation and emphasized that research in the field of materials and processes and equipment has had a tremendous impact on our way of life. He mentioned the desire of the Society to implement its rather small research fund. He also cited certain case histories of important developments stemming directly from research.

Dr. J. M. Purdy, Chief Chemist, The Lowe Brothers Co., who followed Mr. Boyd, with a short case history of research in the paint industry, mentioned among other interesting points, the following:

Research in the Paint Industry:

From an era where materials used were largely natural products, the industry is now at a point where synthetics are the rule, and empirical test methods are being largely replaced by scientifically controlled procedures. Research developments have had a most important effect on varnish-making which used to be limited to a few natural oils and resins. Synthetic resins have increased durability and improved quality, phenolics being one of the most important. Quick-drying varnishes and enamels have resulted from the use of these resins. There are 100 per cent type phenolics which are oil soluble without the use of rosin.

Alkyds are becoming more important every day, with the use so heavy that the production of phthalic anhydride cannot keep pace with the demand. The highest grade enamels today are alkyds, he said, whereas formerly they were oleoresinous. Blending alkyds with urea-formaldehyde and melamine formaldehyde resins has enabled the manufacturers of such products as refrigerators, washing machines, etc., to increase their production many times. On refrigerators, for example, the baking time for the white enamel finish has been decreased from 1 to 2 hours to 15 to 30 minutes. The resulting finish is in no way inferior to the old finish; in fact, in many ways such as color, color retention, and alkali resistance, it is superior.

Vinyl polymers and copolymers used in protective coatings are inert to alkalies and soaps.

Dr. Purdy referred to important developments in oil chemistry and also mentioned important advances in pigments. He cited the important work that A.S.T.M. Committee D-1 on Paint, Varnish, Lacquer, and Related Products is doing, particularly along lines of test methods.

Fundamental studies on linseed oil bodying have given us new and better formulas. Resin emulsion paints have come into wide use as a result of intensive research.

Mr. Nason gave some very interesting facts about the importance of research as concentrated in the Dayton area. Much of our knowledge of aircraft had stemmed from the work of the Wright brothers who were Daytonians, the last of the famous two brothers having died there just prior to the meeting. The important work of Kettering and Deeds, in developing the automotive ignition system and the starter, was cited; also the fact that just twenty-five years before our meeting there had gone on sale in Dayton a motor fuel in which ethyl fluid was used—one of the most significant developments in the automotive industry, and that President Boyd had an important part in that work with Messrs. Kettering, Midgley, and Hochwalt (Mr. Hochwalt was at the meeting). In short, the development of Dayton as an important industrial cen-

Ohio Valley District Council *pro tem*

J. W. Bolton, *Chairman*
The Lunkenheimer Co.
Cincinnati, Ohio

R. R. Bowser
Bowser-Morner Testing Labs.
Dayton, Ohio

E. W. Fasig
The Lowe Brothers Co.
Dayton, Ohio

A. C. Goetz
Eagle-Picher Co.
Cincinnati, Ohio

William Heilig
William Powell Co.
Cincinnati, Ohio

Archibald Hurtgen
Henry Vogt Machine Co.
Louisville, Ky.

H. K. Nason
Monsanto Chemical Co.
Dayton, Ohio

H. C. Nutting
H. C. Nutting Co.
Cincinnati, Ohio

J. C. Pitzer
The Formica Insulation Co.
Cincinnati, Ohio

F. C. Smith
Tube Turns, Inc.
Louisville, Ky.

ter was an excellent case history of research. He further stressed the change in research techniques, the mass attack that is now used in large organizations, and the necessity of careful coordination and understanding of the method of approach and the solution of the problem.

In closing the meeting, Mr. Burns, Chairman of Committee D-20, did not so much cite case histories as he did make a strong plea for close coordination between the research worker on the one hand, and the man who has to apply the fruits of his research, on the other. If the maximum benefits are to come from the millions and billions of dollars spent on research, it is essential that there be intelligent study of the data that are being developed, and how the information can be used in and by industry for the benefit of all of us.

Philadelphia Meeting on Petroleum

PRESIDENT T. A. Boyd and E. T. Knight, of the Atlantic Refining Co., were the two speakers at an interesting meeting sponsored by the Philadelphia District at the Franklin Institute on February 24, the general subject being "Petroleum Products—Production, Consumption and Research." This meeting had been arranged for the district council by H. M. Hancock, Atlantic Refining Co. Past-President T. G. Delbridge presided as chairman and, as always, did an excellent job, tying in the Society interests, giving just the right information in introducing the speakers, and stimulating discussion at the close.

While each speaker touched on all three phases of the problem, that is, the question of consumption, production, and research, each stressed a different aspect, Mr. Boyd covering especially the importance and the benefits of research while Mr. Knight, who is Petroleum Economist of his company, was concerned essentially with the question of supply and how much longer there would be plenty of petroleum.

Since it is hoped much of President Boyd's address can be published in the May BULLETIN, only brief comments are recorded here. He stressed the tremendous increase in research activities, as compared with a few years back, and also gave some case histories as conclusive evidence of the tremendous value coming from well-conducted and continued research. At the Philadelphia meeting his case histories involved automotive fuels and the Diesel engine.

Mr. Knight, who is in daily touch with the petroleum supply situation, gave the audience of about 125, his best "guesstimate" on the situation for the next ten years, and also his reaction on the situation for the second decade ending in 1967.

At the close of World War II in the United States there were about 20 billion barrels of developed reserves which were available to meet the closing war demands of about 5,640,000 bbl. daily. For the next three years the average demand will reach a figure of about 6,100,000 bbl., and by '57 it is expected to be about 7,500,000 daily. To meet the average demand over the next ten years the oil industry is expected to find and develop some 26 billion barrels of crude, and Mr. Wright predicts that our imports are going to exceed exports by about 360,000 bbl. daily. For a more distant period, under reasonably normal conditions it is possible that our average daily use may reach 7,600,000 bbl., to be met by imports of 540,000 bbl. daily to supplement the production from new discoveries and developments of about 25 billion barrels. He stressed the fact that world reserves excluding those in our country are considered adequate to meet long-term demands but refining expansion and improved transportation are essential. We will need to place more dependence upon outside reserves. An increasing portion of our fuel will come from natural gasoline and related products. (Mr. Boyd had stressed the important research on the Fischer-Tropsch process and the fact that two huge plants are being completed now to use methods based on that process.)

Mr. Wright mentioned that today the oil industry is spending upwards of $675,000,000 a year searching for new reserves. Management must consider spending even more money, particularly on new instruments as the search gets into deep horizons and discovery of new fields becomes more difficult. A most important result of new techniques resulting from research is the fact that today we may recover as much as 75 per cent of the oil in place, as compared with half that figure in the past. He also stressed the great responsibility which the petroleum consuming equipment interests have in this whole picture in producing units which will give better utilization of petroleum product potentialities. There is great need for close cooperation between research and production in the manufacture of consuming units and their relation to the oil industry.

"When Metal Breaks" at Philadelphia District Meeting

AT LEAST 200 metallurgists and others concerned with metals, including many members of A.S.T.M. Committee A-1 on Steel, heard two thought-provoking discussions on the subject "When Metal Breaks" at the Benjamin Franklin Hotel on February 3. Dr. Oscar J. Horger, Chief Engineer, Railway Division, The Timken Roller Bearing Co., spoke from the practical standpoint, and Dr. J. H. Holloman, Research Laboratory, General Electric Co., covered the subject from the theoretical standpoint. The meeting was sponsored by the Philadelphia District during the February meetings of Committee A-1 on Steel. There were about 100 present at the dinner and over 200 during the technical discussion. The program had been arranged by District Vice-Chairman A. O. Schaefer, of the Midvale Co., who presided as technical chairman. District Chairman Judson Vogdes introduced some of the men at the speakers' table prior to the technical session, and A.S.T.M. Vice-President J. G. Morrow extended greetings.

The interesting discussion period which followed the two talks and the flurry of requests for copies of the remarks leave no doubt of the intense interest in this subject. Since it is not planned to publish the papers, and because of the difficulty of covering adequately in a short news article even the high points of the remarks, it is thought that references to some of the published works of the two speakers would be of service to those interested. Dr. Holloman has recently co-authored a book, "Ferrous Metallurgical Design," with L. J. Jaffe, published by John Wiley & Sons, this book having been reviewed in the October, '47 ASTM BULLETIN. He is also planning to compile a paper which will be printed, and reference will be made to this in a later BULLETIN.

Dr. O. J. Horger

Dr. Horger, whose remarks were of a real practical nature involving matters of design, use of shot-peening, etc., has suggested that the following four references would be of interest along the lines of his talk:

"Stressing Axles and Other Railroad Equipment by Cold Rolling," O. J. Horger, ASM book on Surface Stressing of Metals, 1947, pp. 85–142.

"Design of Crankpins for Locomotives," O. J. Horger and W. I. Cantley, *Journal of Applied Mechanics*, March, 1946, Vol. 13, No. 1, pp. A17–A33.

"Fatigue Strength of 5¼-in. Diameter Shafts as Related to Design of Large Parts," O. J. Horger, T. V. Buckwalter and H. R. Neifert, *Journal of Applied Mechanics*, September, 1945, Vol. 12, No. 3, pp. A149–A155.

NACA Conference on Aircraft Engine Stress Analysis, Flight Propulsion Research Laboratory, Cleveland, Ohio, November 13, 1947.

Each speaker used a number of slides and, with a great amount of knowledge and "know how" of their subject, really did a fine job in their presentation. This is considered one of the most successful district meetings yet held.

Dr. J. H. Holloman

Inventors Council

A CIRCULAR outlining the organization and functions of the National Inventors Council, comprised of 16 nationally known scientists, inventors, and industrialists, has been released by the Office of Technical Services, Department of Commerce. Dr. Charles F. Kettering, retired vice-president in charge of research, General Motors Corporation, is chairman of the Council.

The circular describes the Council as a "clearing house for inventions and ideas which will assist the Army, Navy, and other public agencies in solving technical problems affecting the national defense and welfare."

To this end, the Council encourages private citizens to submit inventions and ideas which they believe will contribute to national defense and welfare. The Office of Technical Services provides the Council a small staff of technical experts in Washington to handle the Council's administrative and clerical work. Copies of the circular and summary statements of technical problems confronting the Army and Navy are available from the Council on request. Communications should be addressed to National Inventors Council, Department of Commerce, Washington 25, D. C.

American Standard for Dry Cells and Batteries

THE fifth edition of the American Standard Specification for Dry Cells and Batteries, approved by the American Standards Association on August 6, 1947, is now available as Circular C466 of the National Bureau of Standards. The new specification covers the first-grade product of manufacturers and includes all the types of batteries commonly used by the public. Its technical requirements have also been incorporated into a revision of Federal Specification W-B-101.

Advances in the dry-cell industry since the last previous specification of this type was issued in 1941 are incorporated in the fifth edition. For example, the small sizes of dry cells, including flat or miniature cells, receive more emphasis. Also included are specifications for radio battery packs combining low voltage for the A circuit and a higher voltage battery for the B circuit, a more complete standardization for hearing aid batteries, and standardized socket connections for radio A, B, and C batteries. In addition, there have been increases in the requirements of some of the old, established tests.

Circular 466 may be obtained at a cost of 10 cents from the Superintendent of Documents, Washington 25, D. C., or from the American Standards Association, 70 East 45th Street, New York, N. Y.

Saga in Steel and Concrete

KENNETH BJORK, Professor of History at St. Olaf College, has written a most interesting publication entitled "Saga in Steel and Concrete," based on the activities of Norwegian engineers in America. Published by the Norwegian-American Historical Association, Northfield, Minnesota, this book can be procured at $4. The author, who was granted a Research Fellowship for this work, has made a study of leading Norwegian engineers and architects as leaders in the development of various fields in America.

It is impossible to note individually the men whose activities and work are described in this publication, since there are so many, but it is of particular interest to review the chapter entitled "A Philadelphia Story" which includes very interesting details of the early work of Tinius Olsen and his design and development of the testing machine, and his work in making this machine an essential part of American industry. Other A.S.T.M. members are referred to in the publication including Andrew Lundteigen of Ash Grove Lime and Portland Cement Co., Prof. Inge M. Lyse, so active in the field of concrete, and among others Ludwig Skog, of Sargent & Lundy, Inc.

The author has compiled a very readable and interesting book of especial interest to those of Norwegian descent.

Error in Steel Castings Specifications

A TYPOGRAPHICAL error has crept into the Tentative Specifications for Alloy-Steel Castings Suitable for Fusion Welding for High-Temperature Service (A.S.T.M. Designation: A 217 – 47 T), as printed in the 1947 Supplement to Part I-A of the Book of A.S.T.M. Standards and the March, 1948, A-1 Piping Compilation. The error occurs in the recommended temperature range for stress relief annealing and should be corrected as follows:

page 269, Supplement; page 206, Piping Compilation—In Section 3(*f*) change the temperature range for stress relief annealing castings of grades WC1, WC2, WC3, and WC4 from the present "1100 to 1200" to read "1100 to 1250" F.

Error in Report on Rubber

AN ERROR has recently been called to the attention of the Editors in the report of Subcommittee XIV on Abrasion Tests (Committee D-11), entitled "Report on Correlation of Laboratory and Service Abrasion Tests of Rubber Tire Treads," which appeared in the May, 1947, issue of the ASTM BULLETIN.

On page 78 in item 2 (*d*) which states, "Correlation is not generally good when comparing various grades of carbon black," the *not* is in error. It should read, "Correlation is generally good. . . ."

Committee Week

(*Continued from page 12*)

Committee B-8 on Electrodeposited Metallic Coatings

A very high percentage of attendance by its membership and active participation in meetings of all of its subcommittees as well as its main committee featured the meeting of Committee B-8.

The Subcommittee on Specifications, Papers, and Definitions is currently reviewing all existing tentative specifications of the committee through task groups. The subcommittee also laid plans for participating in the Symposium on Bearing Metals and Their Lubricants which is planned for the June, 1949, meeting of the Society.

The Subcommittee on Conformance Tests voted to accept in principle a modified rating procedure for copper-nickel-chromium plating on steel based on photographic standards. The subcommittee also voted to cooperate in exposure tests of the American Electroplaters' Society project on the effect of surface finishing of non-ferrous base metals on the protective value of electrodeposited coatings.

The Subcommittee on Performance Tests is currently reviewing the Method of Test for Local Thickness of Electrodeposited Coatings (A 219) in cooperation with Committee A-5 of the Society. Through another group, this subcommittee is studying existing porosity tests to determine their reproducibility. Another group of the subcommittee is studying microhardness and also the applicability of the Jacquet adhesion test. A fourth section of this subcommittee, on luster, has just been organized and is currently reviewing the applicability of various commercially available instruments to measurements of this property.

The Subcommittee on Electroplating Practice has nearly completed a recommended practice for the preparation of high-carbon steel for plating and has organized sections on the preparation for plating of zinc-base alloy die castings, copper and copper alloys, stainless steels, and aluminum.

The Subcommittee on Supplementary Treatments for Metallic Coatings appointed groups to survey its field thoroughly.

Committee B-9 on Metal Powders and Metal Powder Products

A new Glossary of Terms Used in Powder Metallurgy which has been prepared by Committee B-9 will be published shortly. This glossary defines a total of 130 terms. The committee did not participate in Committee Week in Washington, but met a short time previously in New York on February 16 and 18.

It was announced that work has also progressed on the design of tensile test bars applicable to powder metallurgy products. Two bars are contemplated, one flat and the other to be machined.

The Subcommittee on Metal Powders reported progress on the round-robin compressibility tests being conducted in the various members' laboratories. In cooperation with Committee E-3 on Chemical Analysis of Metals of the Society, work has been undertaken to develop test methods for oxygen content, the insolubles, and the free and combined iron in sintered metals. Progress is also reported on a method of particle size determination by the use of the Roller air analyzer.

The Section on Bearings is developing a list of standard sizes for powdered metal bearings and has reached substantial agreement on press fits and running clearances. When this work is completed it will be added as an appendix to the Specifications (B 202) for Metal Powder Sintered Bearings (Oil Impregnated). Another section is reviewing the need for adding other alloys to those now covered in the Specifications for Sintered Metal Powder Structural Parts (B 222). The Section on Cemented Carbides is developing a method for transverse rupture testing.

Committee C-2 on Magnesium Oxychloride Cements

Committee C-2 held its first meeting since organization, preceded by a luncheon. Considerable progress was reported by the Subcommittee on Methods of Test, and as a result of action taken at meetings of this subcommittee, recommendations were presented to the main committee and accepted for the publication of nine tentative methods of test consisting essentially of basic tests on oxychloride compositions. Progress was reported on the formulation of three other tentatives which are expected to be completed by June. The Subcommittee on Specifications has not held a meeting pending the completion of preliminary work on test methods by the Subcommittee on Methods of Test.

Committee C-8 on Refractory Materials

Committee C-8 recommended the adoption as standard of a tentative revision involving the addition of a new section on test samples required in three standards covering refractories for heavy-duty and moderate-duty stationary boiler service, respectively, and for incinerators (C 64, C 106, and C 153). Tentative revisions covering small changes in the Specification for Ground Fire Clay as a Mortar for Laying-Up Fire-clay Brick (C 105) and Method of Panel Spalling Test for Fireclay Plastic Refractories (C 180) were approved for submission to letter ballot. Progress was reported on cooperative research work on load tests at several universities including Alfred, Iowa State, Missouri, and Penn State.

As a result of interest expressed in studying the disintegration of refractory materials due to carbon monoxide, a new subcommittee has been formed. This subcommittee presented a program of study which will include the chemistry of the process, rate of disintegration, rate of attack and a review of literature.

The Editorial Subcommittee reported the publication of the newly revised Manual of A.S.T.M. Standards on Refractory Materials, the first revision since 1943. This 260-page book gives all of the A.S.T.M. specifications and tests on refractories, definitions, data on standard samples, and several industrial surveys.

Committee C-11 on Gypsum

Committee C-11 plans consideration of the need for a specification on artificial or synthetic gypsum. Action on standards included recommendations for discontinuing the Specifications for Gypsum Pottery Plaster (C 60) and Calcined Gypsum for Dental Plasters (C 72). A tentative revision has been recommended in the Specifications for Gypsum Plaster (C 28) which would change the strength requirements from tensile to dry compressive on 2-in. cubes.

Committee C-12 on Mortars for Unit Masonry

Committee C-12 approved for committee letter-ballot a new tentative specification for mortar for unit masonry covering mortars of four types and including two sets of requirements, namely, (1) property requirements in which the acceptability of the mortar is based upon the properties of the ingredients and the properties of samples of the mortar mixed and tested in the laboratory, and (2) proportion requirements in which the acceptability of mortar is based upon the properties of the ingredients and the proportions of these ingredients. Only one of these two properties will apply to a single purchase.

As part of the report of the Research Subcommittee, F. O. Anderegg outlined his studies on waterproofing compounds which will be presented as a technical paper at the 1948 A.S.T.M. Annual Meeting in Detroit.

Committee C-15 on Manufactured Masonry Units

Committee C-15 announced the organization of three new subcommittees covering acid-resistant brick, flue linings, and drain tile, respectively. The last-named material was transferred to the committee as a result of the disbandment of Committee C-6 on Drain Tile. Included in the actions taken were recommendation for advancement to standard of Specification for Vitrified Clay Filter Block for Trickling Filters; continuance as tentative of Specification for Glazed Masonary Units (C 126 T); revision of the three specifications on concrete masonry units; revision of the Specification for Facing Brick (C 216) covering the surface coloring to be applied to a brick; and a revision of the Specification for Building Brick (C 62) which will

place the footnote covering the strength requirements for four grades of brick into the specification itself. Three new materials are to be studied from the standpoint of standardized specification requirements, namely, adobe, pumice, and perlite.

Committee C-16 on Thermal Insulating Materials

Committee C-16 commemorated its 10th anniversary during Committee Week. A history of the activities of the committee read at the meeting will be distributed to all members. A resolution in memory of the late J. H. Walker, the first chairman of Committee C-16, was passed and placed on the record. A reorganization plan presented and enthusiastically received by the members present will be further reviewed and submitted to letter-ballot of the entire membership. This plan embodies essentially a consolidation of subcommittees into three groups according to the nature of activity, each under the direct responsibility of the chairman and each of two vice-chairmen, respectively. A feature of the reorganization would be the formation of a planning subcommittee which will coordinate all activities of the committee, especially that of research.

Among the activities reported by the several subcommittees were: a correlative study of temperature effects on various types of thermal insulation, methods of measuring surface temperatures, thermal diffusivity and emissivity; a combined desiccant and water method of test for water vapor permeability for sheet materials was approved for letter-ballot which will replace the existing tentative method (C 214 T); a method for measuring conductivity of pipe insultion, similar to C 177, Method of Test for Thermal Conductivity of Materials by Means of the Guarded Hot Plate, is being studied.

Committee C-17 on Asbestos Cement Products

The Subcommittee on Methods of Test reported progress in the consideration of four test methods covering roofing shingles, siding shingles, corrugated board and flat sheets, respectively. It is expected that definite recommendations covering these test methods will be made at the time of the next meeting. The Subcommittee on Specifications reported that it will synchronize its activities with that of the Subcommittee on Test Methods and their intention will be to coordinate Federal and A.S.T.M. specifications. Some review was conducted on the Federal specifications covering siding and flat board specifically. As a result of discussion, a special study group was authorized to review the need for activities on significance of tests.

Committee C-18 on Natural Building Stones

Committee C-18 was successful in arousing interest in specifications on two varieties of natural stone roofing slate and marble. The specification for slate is believed to be sufficiently complete to offer as tentative but due to the fact that none of the slate producers were present at this meeting, the specification was held in abeyance in order to give them an opportunity to offer criticisms. A proposed basis for specifying marble for exterior uses and classifying the present products into grades received considerable discussion. No agreement could be reached on the type of requirements to be used in a specification and the consensus was that further research was necessary. Two new test methods were recommended for submission to letter-ballot of the committee covering the procedure for determination of durability of slate and for determining the resistance of crystalline stones to the combined effort of temperature cycles and with salt solutions.

Committee D-1 on Paint, Varnish, Lacquer, and Related Products

There were meetings of some fifty subcommittees and sections of Committee D-1.

Following the main meeting of Committee D-1, the following two interesting papers were presented:

"The Measurement of Transparency of Surface Coatings" by Roy Kienle, J. Gross, L. A. Melsheimer, and E. I. Stearns, Calco Chemical Division, American Cyanamid Co.

"A Method of Testing for Hiding Power" by Fred Schmutz and J. Gallagher, New Jersey Zinc Co.

The large number of meetings is an indication of the activity in this committee which has under consideration many new and interesting problems on the evaluation of paint and paint materials. It is accordingly possible to present here only a brief résumé of the various testing matters that are under development.

The Subcommittee on Varnish is studying the development of new methods which include tests for drying time, nonvolatile matter, reactivity, alkali resistance, viscosity of transparent liquids, and color of dry and transparent films. Available methods and specifications for phthalic anhydride will be studied prior to establishing standard methods.

New developments and increasing use of resins have resulted in the organization of some twelve task groups to consider the various types and tests for resins. The materials to be studied include rosin esters, alkyds, nitrogen resins, phenolics, vinyl resins, and natural resins. The tests include procedures for nonvolatile matter, acid and unsaponifiable matter, softening point, viscosity and solubility, refractive index, color, and qualitative analysis.

Physical test methods for paint films are continually being studied. Tests under development cover adhesion of paint films, measurement of film thickness, hardness tests, and electrical resistance of films; also water absorption and specific gravity of pigments.

The Subcommittee on Drying Oils presented new Tentative Specifications for Dehydrated Castor Oil; a test for heat bodying rate has also been completed. Work is being undertaken on a "break test" of drying oils and on the acetone test.

The Subcommittee on Accelerated Tests is actively engaged in preparing methods covering humidity testing, immersion testing, and the preparation and cleaning of steel test panels. Methods for determining the cleanliness of test panel surfaces are also being studied. Operation of the light and water exposure apparatus is undergoing further study in a third cooperative test program which will include the use of deionized water.

The Subcommittee on Optical Properties recommended publication as tentative of the revised Method of Test for Specular Gloss of Paint Finishes with a few minor changes. This method was appended to the paper on "The Gloss Measurement of Paint Finishes" by R. S. Hunter in the ASTM BULLETIN for January, 1948. Definitions for gloss and color are in preparation and a study is being made of procedures for preparation of panels for gloss measurement.

Specifications for pigments are being very actively studied by some twelve task groups. This includes a review of present specifications and development of purchase requirements for new pigments. Recently completed are specifications for copper powders for use in anti-fouling paints, and for copper phthalocyanine blue. Those under development include specifications for red iron oxide pigment, calcium carbonate, and putty. Revisions were recommended in the specifications for red and brown iron oxide pigments, venetian red, para red toner, toluidine toner. A number of present tentative specifications were also recommended for adoption as standard.

The Subcommittee on Cellulosic Coatings reported the completion of new Tentative Specifications for Raw and Cold-Pressed Castor Oil for Use in Lacquers.

Traffic paints are being extensively studied by another subcommittee which reported the completion of a method for evaluating the degree of resistance of traffic paint to bleeding. Other subjects being developed are a test for measuring night visibility and an accelerated test for traffic paint durability; also a test for degree of settling of traffic paints.

The Subcommittee on Methods of Chemical Analysis has under development methods of analysis for zinc dust pigments (metallic zinc powder) which will include procedures for determining oils and fatty matter, calcium, lead, iron, cadmium, chlorine, and sulfur. Task groups have also been appointed to prepare methods of analysis for chrome pigments and for blue pigments.

Committee D-2 on Petroleum Products and Lubricants

Committee D-2 furthered its many projects at a three-day meeting at which some sixty sessions were held.

One of the highlights was a Symposium on Service Experience with Inhibited Turbine Oils sponsored by Technical Committee C on Turbine Oils at which the following four papers were presented:

"Steam Turbines and Their Lubrication" by C. D. Wilson.
"An Evaluation of Inhibited Turbine Oils *versus* Uninhibited Turbine Lubrication" by M. D. Baker.
"Service Experience with Turbine Oils" by C. L. Pope and O. V. Sprague.
"The Care of the Lubricant and Maintenance of the Lubricating System for Central Station Turbine Equipment" by E. F. Walsh.

These papers will be published in the ASTM BULLETIN.

Another interesting session was on Tuesday evening when the Navy Cooperative Committee on Fuels and Lubricants sponsored several presentations of studies by the Navy Department of problems encountered in the utilization of fuels and lubricants.

Technical Committee A on Gasoline presented a revision of the Standard Method of Test for Tetraethyllead in Gasoline which now uses only the lead chromate procedure. A revision will be made in the gum content requirement of the Tentative Specifications for Gasoline (D 439). A new section on laboratory bench tests for determining sludge- and varnish-forming tendencies of gasoline has been appointed.

In Technical Committee B on Lubricating Oils a task group will study the measurement of extreme pressure gear lubricants and their relationship to service. It was recommended that a research division study the reproducibility of engine methods for testing extreme pressure lubricants. A study group is to review and make recommendations on the present viscosity classification (S.A.E. Nos.) of lubricants. A Symposium on Industrial Gear Oil Lubricants is being planned for the June meeting of this technical committee.

Technical Committee C on Turbine Oils presented a new Tentative Method of Test for Interfacial Tension of Oil Against Water by the Ring Method. This technical committee has prepared a lubrication recommended practice which deals with cleaning and care of lubrication systems and also important design features in lubrication systems. A study will be made of compatibility of turbine oils.

Technical Committee E on Burner Fuel Oils completed revisions in the Tentative Specifications for Fuel Oils (D 396) which will be submitted to the Administrative Committee on Standards for early publication.

Specifications for Distillate Diesel Fuel Oils prepared by Technical Committee F on Diesel Fuels have been completed and are being coordinated with the revisions in the specifications for burner fuel oils. A new research division is to be appointed on calorific values of petroleum products which would include, among other things, consideration of heating value of Diesel fuels.

Technical Committee G on Lubricating Grease has been very active, as evidenced by several recommendations on Standards and the number of other subjects under consideration. The Test for Evaporation Loss of Lubricating Greases and Oils published as information last year was recommended for approval by A.S.T.M., with revisions changing the time of test from 23 to 22 hours and substituting a flow meter for the pressure gage and calibrated orifice. A new Test for Performance Characteristics of Wheel Bearing Greases is to be published as information. The Method of Test for Cone Penetration of Lubricating Grease (D 217) was recommended for adoption as standard. The water resistance of grease is undergoing study and this may develop into a symposium. Work is actively under way on further improving the Methods of Analysis of Grease (D 128) with respect to free fat determination, analysis of greases containing asphalts, and determination of coexiting free acid and free alkali. A program is planned to determine the effect of metals on greases, and, conversely, the effect of greases on metals.

Another section is investigating the thixotropic behavior of greases by three methods; namely, penetration, power input into the motor of a motorized worker, and pressure drop in a circulating system through a capillary. This work and other activities of this section will be described in a complete report to be published.

Technical Committee G is sponsoring a Symposium on Functional Tests for Ball Bearing Greases to be held at the A.S.T.M. June meeting, in Detroit, the week of June 21. The symposium will comprise the following four papers:

"Grease—An Oil Storehouse for Ball Bearings" by D. F. Wilcock and Marshall Anderson.
"Some Anti-Friction Bearing Grease Testing Machines Available at Beacon Laboratories" by M. Herbst, W. A. Prendergast, R. S. Barnett, W. J. Finn, and P. O. Puryear.
"Factors Affecting Simulated Service Tests of Greases" by S. M. Collegeman and J. R. Belt.
"Service Experience with Grease" by C. L. Pope and W. T. Everitt.

Technical Committee H on Light Hydrocarbons submitted revisions in the Test for Vapor Pressure of Petroleum Products (Reid Method) (D 323) which makes the method applicable for aviation gasoline. The changes were approved after cooperative study by fifteen laboratories, with the results indicating good reproducibility. The Method for Determination of Butadiene Content of Polymerization Grade Butadiene by Koppers-Hinckley Method, published as information last year, is recommended as an A.S.T.M. tentative. The following three methods were presented for publication as information: separation of butadiene in dimer fractions; determination of dimer content, and procedure for nonvolatile content. Presented for publication as information also were volume correction and specific gravity conversion tables for liquefied petroleum gases. Proposed methods for sampling liquefied petroleum gases, prepared in cooperation with Committee D-3, were also approved for publication as information.

Technical Committee J on Aviation Fuels reported a favorable letter-ballot on the new grade 115/145 for inclusion in the Specifications for Aviation Gasolines (D 910). This addition is subject to letter-ballot of main Committee D-2.

Technical Committee K on Cutting Oils reported sections had been organized on analytical tests, physical tests, cutting tests, and film strength tests. Also, a draft had been prepared of definitions and nomenclature covering various types of cutting fluids.

A new Technical Committee L on Tractor Fuels was organized in Chicago, Ill., on January 9, 1948, following a Forum on Tractor Fuels at which the following five technical papers were presented:

"Tractor Statistics as Related to the Farmer" by H. E. Everett.
"The Farmers' Interest in Tractor Fuels" by E. L. Barger.
"A Review of Tractor Requirements as Related to Fuels" by Ramon Bowers.
"The Complexity of Tractor Fuels and Taxation" by A. B. Anderson.
"The Effect of State Tax Regulations and State Specifications on Tractor Fuels from the Petroleum Industry Standpoint" by C. N. Hinkle.

The above papers are now being prepared for publication.

The Division on Combustion Characteristics reported that the extensive A.S.T.M. Manual of Engine Test Methods for Rating Fuels was nearing completion and that the 335-page book would be available early in April. Consideration is being given to a study of the reproducibility of each of the five engine test methods. Action was taken to publish as information in the 1948 D-2 Report a description of the electronic detonation meter which is under consideration for optional use in the engine test methods.

Subcommittee XI on Determination of Inorganic Elements in Lubricants recommends the adoption as standard of the Tentative Methods of Test for Sulfated Residue for Lead, Iron and Copper in New and Used Lubricating Oils (D 810), and Methods of Chemical Analysis for Metals in Lubricating Oils (D 811).

Subcommittee XIII on Neutralization Number and Saponification recommended approval by the Society of the Proposed Method of Test for Acid and Base Numbers of Petroleum Oils by Alpha-Naphtholbenzene Color Indicator which was published as information last year. An important editorial change is being made in the title substituting "Neutralization Number" for "Acid and Base Numbers." The present test using color-indicator titration (D 663) will be withdrawn.

Subcommittee XV on Measurement and Sampling has been collecting up-to-date information on sampling and gaging which, when completed, may be issued in the form of a Manual. Separate sections are actively engaged in reviewing drafts on

the following subjects: gaging procedure; measuring apparatus and its calibration; units of measurement, calculations and conversion tables; tank calibration; and sampling.

Committee D-3 on Gaseous Fuels

Meetings were held by Subcommittees on Complete Analysis of Chemical Composition of Gaseous Fuels, and on Determination of Calorific Value of Gaseous Fuels—two active subdivisions of Committee D-3.

The Subcommittee on Analysis has had under way for several years a comprehensive series of tests on the analysis of prepared samples of gases by a mass spectrometer and also by chemical methods. These studies have been carried on by some 34 cooperating laboratories. The data obtained indicate that analysis can be successfully made by the mass spectrometer. The committee accordingly prepared a Proposed Method for the Analysis of Natural Gases by the Mass Spectrometer, which had been circulated for review prior to the meeting. A number of suggestions were considered by the committee and a revised draft will be acted on at the next meeting to be held in October in Atlantic City, N. J., in connection with the annual meeting of the American Gas Association. The committee also discussed the preparation of a method for the analysis of natural gases by volumetric chemical methods.

The Subcommittee on Calorific Value considered several changes in the Tentative Method of Test for Calorific Value of Gaseous Fuels by the Water-Flow Calorimeter (D 900). The revisions concern changes in the specifications for thermometers used in the method and recognition of the use of unit quantities of gas other than the standard cubic foot; in particular, to a cubic foot of gas measured dry at 60 F. and 30 in. of mercury. With these changes the method was recommended for adoption as standard.

Committee D-4 on Road and Paving Materials

Committee D-4 approved recommendations on the following items: the advancement to standard of the Tentative Specification for Calcium Chloride (D 98) and the Tentative Methods of Sampling and Testing Calcium Chloride (D 345); the continuance as tentative of Methods of Sampling Bituminous Materials (D 140) with an editorial revision consisting of the insertion of a new section on scope; revision of the tentative Specifications for Hot-Mixed, Hot-Laid Asphaltic Concrete Base and Surface Courses (D 947); continuance as tentative of Methods of Test for Loss on Heating of Oil and Asphaltic Compounds (D 6); advancement to standard of Methods of Sampling Stone, Slag, Gravel, Sand, and Stone Block for Use as Highway Materials (D 75); and Method of Test for Sulfonation Index of Road Tars (D 872).

A new tentative specification for emulsified asphalts was approved for submission to letter-ballot of the committee. This will replace the five existing specifications, D 397, D 398, D 399, D 401, and D 631. A new tentative specification on asphaltic mixes for sheet asphalt pavements is now ready for letter-ballot of the Subcommittee on Bituminous Paving Plant Operations.

Committee D-5 on Coal and Coke

The most important action taken by Committee D-5 was approval of a proposed Tentative Method of Sampling and Analysis of Coal for Volatile Matter Determination. This test is for use in connection with local ordinances regarding solid fuels. It is intended for use only when the volatile matter determination is the principal item under consideration. This method will present a precise procedure for selecting a sample of coal for obtaining an accurate determination of the volatile matter and will be found very useful in connection with smoke abatement laws of various municipalities.

An important change to be made in the Methods of Sampling and Analysis of Coal and Coke (D 271) will speed up considerably the work of commercial sampling through the use of a new design of riffle sampler. The new riffle has been adopted following a study of several designs made by the committee during the past year. Improvements have also been made in the construction of the shatter test machine for coal and coke.

A cooperative study is under way of methods for determining carbon, hydrogen, and nitrogen in coal and coke. The revised methods will make use of equipment and chemicals now available on the market and probably will shorten the analytical procedures for these determinations.

The committee is considering the desirability of undertaking work on float and sink tests of coal.

Committee D-8 on Bituminous Waterproofing and Roofing Materials

Reports of Committee D-8 subcommittees noted the following activities: a group of definitions are being prepared for subcommittee ballot; two tentative specifications covering asphalt roofing surfaced with mineral granules and powdered talc for mica, respectively (D 224 and D 249), were recommended for continuance as tentative; a new specification was proposed to cover insulating type siding; a study of adhesion of asphalt coating is under way looking to the establishment of a test method; and cooperative tests are in progress on pigment and enamel fixation or color adhesion. A new subcommittee was proposed to establish one or more tests to determine the incompatibility of bituminous materials used in waterproofing and roofing. Agreement has been reached between Committees D-4 on Road and Paving Materials and D-8, on a joint symposium to be given at the annual meeting in 1949 on the subject of accelerated durability tests on bituminous materials.

Committee D-9 on Electrical Insulating Materials

One of the most active groups in Committee D-9 which held a series of meetings in Dayton, Ohio, on February 23-25, 1948, has been the Subcommittee on Electrical Tests. After considerable study, this committee has prepared a low-temperature high-voltage arc-resistance test which will be referred to the Society for publication. The Section on Resistivity Methods also has been making some exhaustive studies. Some five drafts of complete test procedures have been reviewed, one full day of the meetings being devoted to this particular subject. A considerable amount of data obtained from cooperative tests of pin-type electrodes has been compiled and will be presented in a technical paper. Plans were made for a further round-robin study of silver paint as a satisfactory material for electrodes. This work will be undertaken by a new section appointed to consider all types and kinds of electrodes for use with both solids and liquids.

The committee will submit to letter-ballot the use of the term "capacitivity" in preference to "dielectric constant."

The Subcommittee on Insulating Papers reported that it is completing specifications for absorbent insulating paper. The requirements will cover paper made from unbleached sulfate, rag, or alpha pulp which will readily absorb resins and be suitable for use in the manufacture of laminated and impregnated sheet, rod, or tubing for electrical insulation. Plans were made by the Subcommittee on Liquid Insulation to sponsor a third symposium on insulating oils, to be held at the November, 1948, meeting of the committee. The Section on Sludge Tests reported progress n the studies being made to correlate sludge tests with service life. This work is to be expanded to cover inhibited insulating oils. Separate methods for determining sulfur and for dielectric strength have been completed. An important note is to be added to the sludge test regarding the high-pressure oxidation test on highly refined oils. Work is to be undertaken on methods for determining free and combined corrosive sulfur. Work is progressing satisfactorily on the preparation of screening specifications for insulating oils and it is expected that a final draft will be ready for action in June.

Active studies will be started on mineral waxes used for treating electrical insulating materials, and plans were made to compile test methods currently in use for evaluating waxes, including methods for both electrical characteristics and also certain performance tests used in evaluating waxes. Those discussed include procedures for moisture-proofness, volume contraction, congealing point, flexibility, and adherence.

The Subcommittee on Mica furthered its plans for making available a set of reference standards in the form of color negatives for use in classifying and grading

mica. It was decided to proceed with the preparation of a specification for block and film mica for general use. Such a specification is now needed in view of the many applications of mica in the manufacture of electronic tubes and for other uses such as terminal plates, fillers, insulators for keys and jacks, etc. It is proposed that the new specifications would provide requirements for both electrical and visual characteristics. Inquiry is being made as to the need for separate specifications for pasted mica.

Committee D-11 on Rubber and Rubber-Like Materials

Among the important activites at the meeting of Committee D-11 and twenty of its subcommittees were programs of work on two new and important subjects; namely, thread rubber and rubber latices.

At the organization meeting of the new Subcommittee on Thread Rubber it was decided to develop test methods for the physical characteristics of rubber thread. First consideration will be to tests for determining size, modulus or strength, and permanent set. A cooperative study of these three tests will be made by four laboratories.

The Subcommittee on Rubber Latices, organized in Philadelphia on December 10, 1947, held a two-day meeting and decided to confine the work at first to natural latex. There was a thorough consideration of specifications for creamed and centrifuged latex. There is urgent need for these specifications due to the establishment of a number of new sources of rubber following the war, and specifications will assist in the production of a latex of suitable quality. The proposed requirements cover sampling, determinations of total solids, dry rubber content, alkalinity, viscosity, sludge, odor, procedures for copper and manganese, etc. A number of reports were submitted on studies of chemical and physical tests on liquid latex and also latex in solid form.

The Technical Committee on Automotive Rubber, which is under the joint auspices of A.S.T.M. and S.A.E., considered problems dealing with the application of rubber to automotive and aeronautic equipment. Action was taken to submit as tentative a new Method of Test for Volume Resistivity of Electrical Conductive Rubber and Rubber-Like Materials. Decision was also reached on revisions in the Methods of Testing Automotive Air Brake and Vacuum Brake Hose (D 622). Work is under way on specifications and tests for bumpers, rubber mats, and vacuum brake hose.

The Subcommittee on Insulated Wire and Cable completed new specifications for thermoplastic sheaths which are recommended as tentative. Other subjects under consideration are standards for thermoplastic insulated appliance wire and rubber-insulated appliance wire. An electronic method for determining ozone is to be investigated for use in testing wire insulation.

The Subcommittee on Packings will continue its studies of a procedure for determining the tendency of compressed asbestos gaskets to corrode adjacent metal surfaces. In cooperation with other D-11 subcommittees, specifications are in preparation for compressed asbestos sheet and for rubber sheet packing.

Revisions were completed in the Tentative Specifications for Friction Tape for General Use for Electrical Purposes (D 69), and the Specifications for Rubber Insulating Tape (D 119).

An important assignment given to the Subcommittee on Physical Tests was the development of tests for determining coefficient of friction between rubber and other surfaces. This property is especially important for such materials as heels and soles of shoes, flooring materials, and tires.

Work in the Subcommittee on Chemical Analysis includes procedures for GR-S natural rubber determinations, methods for reclaim analysis, and procedures for determining plasticizers in rubber used in contact with gasoline.

The Abrasion Subcommittee submitted revisions in the Standard Method of Test for Tear Resistance of Vulcanized Rubber (D 624). Studies made of the deviations of profile of edges of died-out rubber specimens have been completed and are being described in an article it is hoped to publish soon. A task group is conducting tests on analysis of factors affecting road wear of tires and the correlation of road wear with laboratory tests.

The Subcommittee on Life Tests presented a report on aging of GR-S which is to be published. Further study of the aging of GR-S is being continued and it is planned to hold an informal discussion on this subject at the June meeting in Detroit. This subcommittee also has under way a program in eight laboratories on the study of air oven aging methods. Other matters being given attention include the effect of ozone aging and the effect of light.

The Subcommittee on Hard Rubber reviewed data submitted by six cooperating laboratories on tests of high-, medium- and low-quality stocks. Further tests will, be made on samples from standard formulas in order to determine the degree of reproducibility of the methods being studied.

The Subcommittee on Coated Fabrics has been giving attention to various types of abrasion test methods. A great deal of work is necessary on this subject, especially with regard to standardization. The round-robin on scrub and flex tests of coated fabrics is continuing and various types of scrub testers are being studied.

A relatively new activity in Committee D-11 is the work being done by the Subcommittee on Processibility Tests. Two methods, covering the Test for Plasticity and Recovery by thePa rallel Plate Plastometer (D 92), and the Test for Viscosity by the Shearing Disc (D 927), were recently published as tentative. A new Tentative Method for Determining Scorch Time Using the Mooney Plastometer has been completed and will be submitted to letter-ballot.

Another new activity is that on resilience tests. The first method to be completed has just been published as tenative under the title of Test for Mechanical Properties of Elastomeric Vulcanizates Under Compressive or Shear Strains by the Mechanical Oscillograph (D 945). Other matters under consideration are forced vibration and torsional vibration.

The Subcommittee on Low-Temperature Tests recommended for publication as tentative a torsion test for low-temperature set measurements.

Committee D-13 on Textile Materials

COMMITTEE D-13 on Textile Materials held its spring meeting at the Park Central Hotel in New York City on March 17–19, 1948. The interest in the activities of this committee is evidence by the registered attendance of 206 members and 53 guests, or a total of 259, the largest since the committee was organized in 1914. Meetings were held of some fifteen subcommittees.

The highlight of the meeting was a technical session on Thursday afternoon at which the following three papers were presented:

"The Importance of the Time Factor in the Study of Textile Properties" by Prof. Edward R. Schwarz, Massachusetts Institute of Technology, Cambridge, Mass.

"The Stress Strain Curve as a Laboratory Tool in Textile Research" by Dr. Walter J. Hamburger, Fabric Research Laboratories, Boston, Mass.

"Some Applications of Stress Strain Measurements to the Determination of Fiber Properties" by Dr. Arnold M. Sookne, Harris Research Laboratories, Washington, D. C.

The Subcommittee on Cotton and Its Products acted on an important revision of the Specifications for Cotton Tapes for Electrical Purposes which will now cover woven tapes used in the electrical industry from thicknesses from 0.030 in. down to 0.005 in., inclusive.

The Subcommittee on Man-Made Organic-Base Fibers considered a new technique for determining wet strength. This procedure uses the strip rather than the grab method. A procedure for determining the "shift" of man-made fabrics is under consideration. A progress report describing the shift tester was presented at the meeting.

The Subcommittee on Wool and Its Products completed a revision of the Test Methods and Specifications for Woolen and Worsted Yarns. Progress reports from task groups were made on the following: (*a*) sampling of carpet wool, apparel wool, scoured wool for clean content, and raw wool for grade; (*b*) determination of moisture in scoured wool, top, etc.; (*c*) conversion factor for wool (top-soil-waste relationship). Work is also under way on studies of tests for fineness, shrinkage, and moisture.

The Subcommittee on Asbestos and Its Textile Products reported the completion of an extensive revision of the Standard Specifications and Methods of Test for Asbestos Yarns (D 299). Action was also

taken on a Method of Determining Magnetic Rating of Asbestos Lap.

The Subcommittee on Bast and Leaf Fibers considered the data from a laboratory study of an optional alternative method for determining ethylene dichloride extractable matter. This new method, which requires a much shorter time than the present referee method, will, when approved, be included in the Methods of Testing and Tolerances for Jute Rove and Plied Yarn for Electrical and Packing Purposes (D 681). This committee also has in preparation a series of methods of test for twine.

The Subcommittee on Household and Garment Fabrics will submit to letter-ballot a revision of the Tentative Specifications for Bleached Wide Cotton Sheeting (D 503). The present specifications cover six types of sheeting and are being replaced by the following four types: percale (Type 200), carded percale (Type 180), heavy weight muslin (Type 140), and medium weight muslin (Type 128).

The Subcommittee on Glass Fibers considered an interlaboratory test for comparing breaking strength of raveled strip specimens having the end sections protected with pressure sensitive tape, with others protected with methacrylate solution. A study of abrasion of glass textiles is under way and methods for determining sizing are to be prepared. The need for test methods for decorative fabrics was also discussed.

Another subcommittee that has been very active is that dealing with wool felt. At its meeting a paper by R. R. Stevens was presented on "Laboratory Methods for Evaluating the Felting Power of Wools." This committee has under consideration a number of additional tests for wool felt which include procedures for hardness, stiffness, amount of sizing, mildew and fungi resistance, thickness of soft felts; also specifications for roll and sheet felt. Consideration is being given to a method of test for determining hydrogen ion concentration (pH value) of felt.

The Subcommittee on Pile Fabrics considered the interlaboratory testing program for studying flame test procedures and for determining resistance to insect damage. Methods of testing Kraft yarn were also considered and a review made of methods of evaluating resistance of pile fabrics to spotting.

The newly organized Subcommittee on Hosiery held its second meeting at which replies to a questionnaire on test methods were reviewed. Plans were made for an intercomparison study by some ten laboratories of the du Pont snag tester. There was considerable discussion of the need for service tests of hosiery. A report on this subject, containing a number of suggested methods was discussed. Work is to be undertaken on the development of a stretch test. Replies to the questionnaire indicated that many laboratories were using three types of machines: namely, the Scott pendulum, du Pont tester, and Scott incline plane apparatus. It was decided to draft methods based on these three machines and then to run an interlaboratory comparison on the three methods.

The new Subcommittee on Bonded Fabrics reviewed drafts of proposed methods which cover tests for weight, tensile strength, bursting strength, water absorbency and related properties of nonwoven fabrics.

In the Subcommittee on Test Methods, task groups have been established to develop test procedures on the following subjects: bulk fibers, elastic fabrics, stress-strain curves, thermal transmission, jaws and clamps, calibration of incline plane testers, water resistance, viscosity, methods of quantitative analysis, and procedures for determining copper, manganese, and nickel in textiles. An alternate procedure was presented for inclusion in the Test for Apparent Fluidity of Dispersions of Cellulose Fibers in Cuprammonium Hydroxide (D 539). Revisions under consideration in the Test for Resistance of Textile Materials to Microorganisms (D 684) include the standardization of soils to be used; also a standard soil fabric, pH control, steam sterilization, and other related features. One important decision was to reactivate the task group on fire tests. The meeting of this subcommittee was featured by a report on wear testing. The session was concluded by the presentation of a very interesting and final report of the task group studying the Wyzenbeek precision wear test meter prepared by S. J. Tanenhaus and Gerald Winston of the Textile Research Laboratories, Philadelphia Quartermaster Depot. This report, presented by Mr. Winston, concludes this series of interlaboratory studies. The report, presenting considerable data and some very interesting conclusions, may be published in an early issue of the ASTM BULLETIN.

The Subcommittee on Definitions presented a revision of the term "rayon" which will restrict it to regenerated cellulose type fibers. Action was also taken recommending a definition of the term "estron" as a generic term for cellulose ester fibers.

The Subcommittee on Atmospheric Conditions considered the results of a questionnaire on the subject of standard atmospheric testing conditions. A relative humidity of 65 per cent at a temperature of 77 F. has been recognized and used for some years in testing textile fibers and textile goods. A number of other groups in A.S.T.M. had, however, adopted a 50 per cent relative humidity. Consideration had been given to the proposal advanced by an FSB Technical Committee recommending the establishment of 73.4 F. and 50 per cent relative humidity as the standard atmospheric conditions. This proposal was also being favorably considered by the Technical Committee on Conditioning and Weathering, of A.S.T.M. Committee E-1 on Methods of Testing. The results of this D-13 questionnaire, however, indicated that the textile committee favors very definitely a relative humidity of 65 per cent. However, it was decided to submit to letter-ballot vote a change in the standard temperature from 77 F. to 73.4 F.

Committee D-14 on Adhesives

Considerable activity was shown at Committee D-14 meetings as indicated by the several subcommittee reports. The Subcommittee on Strength Tests reported that a shear test was nearing completion, that round-robin tests are in progress on flexure specimens and a recommended practice for fatigue testing cantilever beams is ready for subcommittee ballot. The Subcommittee on Tests for Permanency is revising the Test Method for Resistance of Adhesive Bonds to Chemical Reagents (D 896) to include a screen test. Round-robin tests are being conducted on the present Recommended Practice for Determining the Effect of Artificial (Carbon-Arc Type) and Natural Light on the Permanence of Adhesives (D 904).

The Subcommittee on Working Qualities has agreed upon a modification of the Green Tack Meter to be built for round-robin tests to determine tack properties and has accepted a proposed method for determining consistency.

A third set of definitions and nomenclature relating to adhesives has now been reviewed and will be submitted to letter-ballot of the main committee.

The subject of shear testing was the principal item in the report of the Research Subcommittee and a section was authorized to work on the problem of developing a test which will give the true shear characteristics of an adhesive. Announcement was made of the organization of a new Subcommittee on Electrical Properties.

A highlight of the meeting program was a talk by A. D. McLaren, Department of Chemistry, Polytechnic Institute of Brooklyn, on "The Fundamental Properties of the Adhesion of High Polymers to Cellulose." This was very well received by those present.

The next meeting of the committee is scheduled for early November of this year in Washington.

Committee D-15 on Engine Antifreezes

In January, A.S.T.M. Committee D-15 held its second meeting since the group was organized late in 1947 in Detroit, with sessions of five subcommittees.

The Subcommittee on Freezing Point Determination made plans for cooperative interlaboratory tests. Data on freezing points of various materials used as engine antifreezes are being compiled.

Another subcommittee is developing performance specifications for hydrometers used in testing engine antifreeze in the field. Hydrometers of this type are used in automobile service stations throughout the country, and the establishment of specifications will accordingly serve a very useful purpose.

The Subcommittee on Physical Properties, in developing its program of work, decided to undertake the study of some eight test methods. These include boiling range, appearance, evaporation rate, heat transfer and specific heat, leakage, creepage, specific gravity, and viscosity.

The Subcommittee on Chemical Properties likewise plans to develop methods of analysis for the evaluation of antifreeze materials. Specific subjects under study are procedures for determining pH value, reserve alkalinity, ash, solids on evaporation, and chemical composition of antifreezes.

There has been a real need for reliable information on approved methods of using and servicing cooling system additives such as antifreezes, cleaners, corrosion inhibitors, and anti-leak compounds and the like. The committee has accordingly decided to compile the necessary information, looking toward issuing a recommended practice or code dealing with mechanical maintenance of cooling systems.

The corrosive and foaming tendencies of antifreeze solutions were considered by another subcommittee. The effectiveness of corrosion inhibitors is now being studied by laboratory tests for screening purposes, engine tests for full-scale evaluation, and car tests for a final check under practical operation conditions. In the case of foaming, this property is usually determined under simulated or actual operating conditions. Various members reported on tests in use in their laboratories in the study of these two characteristics. A task group was appointed to compile this information as a basis for studies to be undertaken by the committee.

Committee D-19 on Water for Industrial Uses

Committee D-19 has requested the Society to publish in the BULLETIN, (see page 34) as information, a method of test for the sampling of steam. The committee feels that this new method will insure the taking of correct samples to determine either moisture in steam by the calorimeter method or impurities in steam by electrical and chemical tests. The American Society of Mechanical Engineers, through its Power Test Code Committee, is cooperating in this work.

Numerous methods for sampling of water and for analysis were reviewed and additions and amendments made thereto. A new method for the determination of nitrates was approved, as well as one for the detection of sulfate reducing bacteria. The committee is looking forward to a panel discussion which it will sponsor jointly with the Joint Committee on Boiler Feedwater Studies at the A.S.T.M. Annual Meeting in Detroit in June. The committee is also planning to organize a new subcommittee to cover the subject of water-borne industrial wastes.

Committee D-20 on Plastics

Considerable activity in the Subcommittee on Strength Properties was reported at the two-day session of Committee D-20 in Dayton, Ohio, on February 26-27. Reviews of a number of test methods resulted in revisions proposed in the tests for brittle temperature of plastics, and the test for stiffness in flexure of nonrigid plastics. It also recommended the adoption of the Method of Test for Tensile Strength (D 651), and Tests for Impact Resistance (D 758) and Tensile and Compressive Strength (D 759) of Plastics at Subnormal and Supernormal Temperatures. A method for determining the bearing strength of rigid plastics either in sheet or molded form was completed. Two procedures are included, one for tension, the other for compression, loading. A new method for determining bond strength or ply adhesion strength of sheet plastic and electrical insulating materials has also been completed.

The Subcommittee on Hardness Properties presented a statement on significance of tests to be included in the Method for Estimating Blocking of Plastic Sheets (D 884). It also recommended the adoption as standard of the Method of Long-Time Tension Tests of Plastics (D 674).

The Subcommittee on Thermal Properties will combine the present methods for measuring and for designating flow properties of thermoplastic materials. Revisions were recommended in the test for deformation of plastics under load. The Section on Flammability is cooperating with the extensive studies on flammability tests of plastic films being carried on with the American Association of Textile Chemists and Colorists and the Society of the Plastics Industry.

The Subcommittee on Optical Properties submitted extensive revisions of the Test for Haze of Transparent Plastics by Photoelectric Cell (D 672). The Tentative Test for Deviation of Line of Sight Through Transparent Plastics (D 881) is to be adopted.

The Subcommittee on Permanence Properties will study tests for gas permeability of plastics and also tests for shrinkage of plastics.

Revisions were offered in the Specifications for Cellulose Acetate Molding Compounds (D 706), for Laminated Thermosetting Materials (D 709), and for Methacrylate Molding Compounds (D 788). The Section on Plasticizers has compiled a list of available specifications and copies have been sent out for review and comment. Formulation of specifications will depend on completion of the necessary test methods for analysis of such materials. Work on such tests is under way in Subcommittee VII on Analytical Methods.

The Subcommittee on Molds and Molding Processes has completed new Recommended Practices for Molding Specimens of Amino Plastics, and a Method of Measuring Shrinkage from Mold Dimensions of Molded Materials. Two other recommended practices also completed cover determining temperatures of standard A.S.T.M. test specimen molds, and determining molded surface temperature of commercial molds.

At the meeting of the Subcommittee on Research, Mr. Walter Gaylis described details of the Universal Plastics Testing Machine developed jointly by the Massachusetts Institute of Technology and the Plastic Materials Manufacturers Association. A description of this machine appeared in the December, 1947, ASTM BULLETIN.

A second paper was presented by Mr. F. W. Reinhart of the National Bureau of Standards on the degradation of plastics. This subject is the one in which the greatest interest was indicated in replies to the questionnaire on research problems which should be investigated by college and university graduates. This list of projects appears in the ASTM BULLETIN for January, 1948.

Particle Size of Pigments; Density of Insulating Powders

The Section on Pigment-Type Materials, of A.S.T.M. Committee E-1 on Methods of Testing, has reviewed a Method of Analysis for the Particle Size Distribution of Pigment Type Materials. The new method is intended for determining the particle size of pigments and similar materials in absolute units as far as the particle shape and refractive index will permit. While it is too time-consuming for extensive use as an acceptance method between buyer and seller, it may be used for two purposes: (1) Since it is one of the fundamental methods of particle size determination, it can be used as a basis of calibration for faster methods such as those involving turbidity; and (2) it can be used for the determination of the particle size of routine samples and is particularly useful in the cases where the particles are of such shape (plates, needles, etc.) where they do not approximately obey Stokes' law. The method applies in its entirety to homogeneous materials. In the case of mixtures, the extent of application is limited by the properties of the components of the mixture. It applies most efficiently to the range of sizes between 0.2 and 20 microns. The lower limit is imposed by the resolving power of the optical microscope, the upper limit usually by the thickness of the particles as related to the depth of focus of the optical system; several levels of focus or several magnifications may be used for the same analysis.

Technical Committee IV on Methods for Density considered the need for a method suitable for use in standardizing powders used as insulation. This determination is particularly important where the insulation will be subject to vibration of various frequencies, jarring, etc. There is agreement that the use of small glass graduates and the employment of manual lifting and dropping operations were not satisfactory for powders which are to be packed into relatively large spaces. The frictional retardation of the relatively large amount of wall surface on the glass graduate introduces and emphasizes effects which are not so prominent in practical conditions. The preparation of an acceptable method will be undertaken. The committee will also study and develop a general method for determining specific gravity which would be applicable to a variety of materials.

Committee E-3 on Chemical Analysis of Metals

The highlight of Committee E-3 meetings was an all-day Symposium on "Organic Reagents for Metal Analysis" featuring talks by four prominent authorities and an exhibit of some fifty pertinent books, at the Shoreham Hotel in Washington. The symposium was held under the auspices of Division D on General Analytical Methods, of which S. E. Q. Ashley, General Electric Co., Pittsfield, Mass., is chairman, and H. Kirtchik, also of G. E., is secretary. These men were instrumental in arranging the interesting session. Abstracts of the papers in the symposium are being prepared for publication in the March issue of the Analytical Edition of *Industrial and Engineering Chemistry*, and they are published elsewhere in this BULLETIN.

At meetings of the main committee and subcommittees additional impetus was given to the extensive program of cooperative work on new and revised methods under way in the committees. A "Photometric Method for Determination of Cobalt in Nickel and Copper-Nickel Alloys" will be submitted to the Society for acceptance as tenative at the annual meeting in June. Also ready for publication as tentative are revisions of the Tentative Recommended Practices for Apparatus and Reagents for Chemical Analysis of Metals (E 50 – 46 T) to cover the addition of requirements for apparatus for titration to a "dead-stop" end point and the extensive revision of the present requirements for the mercury cathode cell and for apparatus for potentiometric titration. An important project getting well started is the study of requirements for analytical balances.

Committee E-4 on Metallography

Committee E-4 activities included organization of a new subcommittee on microhardness methods under the chairmanship of Alexander Gobus, Sam Tour and Company. At a meeting of this subcommittee a lengthy discussion resulted in the methods and procedures for microhardness testing. The meeting was very well attended, the subject apparently being of interest to a great number of people.

Committee E-4 has recognized the need for work on standardization of specimen preparation and procedures for the use of the electron microscope for inspection of metals. This work has been delegated to two of its subcommittees, the subcommittee on photography under the chairmanship of L. V. Foster of Bausch & Lomb Optical Co., and the subcommittee on selection and preparation of samples under the chairmanship of J. R. Vilella of the U. S. Steel Corp. Research Laboratories.

Committee E-4 will sponsor a Symposium on Metallography in Color during the annual meeting of the A.S.T.M. in Detroit from June 21 to 25. Offers of seven papers have been received which cover the applications of color metallography and determinations of exposure for color metallography among other worth-while contributions. L. V. Foster is chairman of the group responsible for organizing this symposium. It is hoped that the symposium will be published as a bound volume subsequent to the presentation of the papers and discussions at the annual meeting.

During the A.S.T.M. Annual Meeting in Detroit, Committee E-4 will also sponsor as part of the main Photographic Exhibit a Section on Photomicrography. This will feature new methods and techniques, not only in the field of metallography, but in work in other materials fields.

Committee E-5 on Fire Tests of Materials and Construction

Among the matters covered in reports of several subcommittees of Committee E-5 were the following:

1. A recommendation for further minor revisions in the Standard Methods of Fire Tests for Materials and Construction (E 119).
2. A special group will study a proposed test on steel beams and girders in an unloaded state.
3. Work is under way at the Forest Products Laboratory and the Underwriters' Laboratory on the refinement of the tunnel test as applied to acoustical and similar finishes.
4. The final draft of the definition of the term "incombustible" has been tabled pending the completion of a proposed tentative method of test for incombustibility of solid materials, this method to be published for information only.
5. Agreement has been reached on one basis for study of a method of test for roof coverings which will not include classification.

A method of sampling was presented by the Subcommittee on Fire Tests of Lumber which will combine into one method the sampling of specimens for both the fire tube tests (E 69) and the crib test (E 160). It was recommended that the two test methods be reverted to tentative status with this revised method of sampling included in both.

Action was taken to form an advisory subcommittee comprising the committee officers and subcommittee chairmen to review standards on fire tests referred to the committee by other technical committees of the Society.

Committee E-6 on Methods of Testing Building Constructions

Committee E-6 and five of its subcommittees held meetings. A draft of a tentative method of Testing Truss Assemblies was approved by the Subcommittee on Trusses, Girders, and Arches and will be sent to letter-ballot of the subcommittee. A draft of a Tentative Test Code for the Laboratory Measurement of Airborne-Sound Transmission Loss of Building Floors and Walls was approved by the Subcommittee on Sound Transmission and will be circulated for comment and criticism. Progress was reported in the work of other subcommittees.

Committee E-9 on Fatigue

Committee E-9 has been working for the past year on the preparation of a Manual on Fatigue Testing. Under the direction of the committee officers this Manual is now rapidly approaching its final form. Six sections of the Manual have already been completed and reviewed.

The two remaining sections were discussed and final revisions were agreed upon during the meeting of the committee in Washington on March 1 when it participated in A.S.T.M. Committee Week. These two sections are those on Testing Procedure and Technique prepared by W. N. Findley of the University of Illinois and the section on Fatigue Testing Machines prepared by O. J. Horger of The Timkin Roller Bearing Co. (The sections previously drafted and approved cover the following: Introduction, R. E. Peterson; Nomenclature, J. M. Lessels; Specimens and Preparation, J. B. Johnson; Presentation of Data, L. R. Jackson; Interpretation of Data, R. L. Templin; Bibliography, T. J. Dolan.)

It is expected that the Manual, for which there is urgent need, will be ready for publication sometime during the summer.

Organic Reagents for Metal Analysis Covered in Washington Symposium

Part of Series Under Division D on General Analytical Methods, Committee E-3 on Chemical Analysis of Metals

An all-day "Symposium on Organic Reagents for Metal Analysis," featuring five papers by four prominent authorities and an exhibit of some fifty pertinent books, was held on March 4, 1948, at the Shoreham Hotel in Washington, D. C. The symposium was under the auspices of Division D on General Analytical Methods of A.S.T.M. Committee E-3 on Chemical Analysis of Metals, in connection with the meeting of Committee E-3 on March 5 held as part of A.S.T.M. Committee Week. This is one of a series of such symposia sponsored by Division D of Committee E-3, which have been found most helpful in keeping the members of the committee informed on subjects of special interest.

S. E. Q. Ashley, General Electric Co., Pittsfield, Mass., chairman of Division D, presided at the morning session of the symposium, and J. W. Stillman, E. I. du Pont de Nemours and Co., Wilmington, Del., Secretary of Committee E-3 presided at the afternoon session. There were about 80 present at the symposium.

Symposium Papers on Organic Reagents for Metal Analysis

Abstracts by Grant Wernimont

Because the symposium was felt to be one of wide interest to analytical chemists, an account of the symposium is to be published in the Analytical Edition of *Industrial and Engineering Chemistry* and will include abstracts of the papers presented (publication of the complete papers is not contemplated at this time). Through the courtesy of the editors of *Industrial and Engineering Chemistry*, and of Mr. Grant Wernimont, Eastman Kodak Co., who prepared the abstracts, they have been made available for publication in the Bulletin and are given below.

Organic Reagents for Gravimetric Analysis

John F. Flagg, General Electric Co., Schenectady, N. Y.

Two types of organic compounds are useful as reagents for inorganic ions; (1) compounds which form chelate complexes and (2) compounds which form salts. Examples of chelate complexes are dimethyl glyoxime with nickel and 8-hydroxyquinoline with aluminum. The insoluble precipitate formed when phenylarsonic acid is added to a solution of zirconium illustrates the salt-like compounds. The discussion was limited to two reagents which fell in the first classification.

Thionalide (*p*-aminonaphthalide of thioglycolic acid) is a reducing agent and it forms stable complex compounds with metals which form slightly soluble sulfides. This crystalline solid compound was studied rather thoroughly during the last decade by R. Berg and his coworkers but not much has been published about it in English. It is not available commercially.

The following advantages of thionalide over hydrogen sulfide as a metal precipitant were cited:

1. It can be used in solutions of nitric acid up to half-normal concentrations.
2. The metal precipitates do not drag down soluble metal ions by coprecipitation as is the case with sulfides.
3. Lead and cadmium do not form precipitates in acid solution which makes certain separations possible which are impossible when hydrogen sulfide is used.
4. The filtrate from a thionalide separation can be conveniently used for analysis of nonprecipitated metals because the excess reagent can be converted to an insoluble flocculent compound by means of iodine.

The main disadvantage to the use of thionalide is its reducing property which makes the removal of strong oxidizing agents absolutely necessary. The precipitate with copper also forms rather slowly. Copper, silver, bismuth, thallium, ruthenium, and palladium all have been determined gravimetrically by means of thionalide. By precipitating in the presence of different combinations of hydroxide, tartrate, and cyanide many convenient separations of metals among the sulfide groups are possible.

Picrolonic acid (1-*p*-nitrophenyl-3-methyl-4-nitro-5-pyrazolone) is another new organic reagent. It forms a crystalline precipitate with calcium which is slightly more soluble than calcium oxalate; calcium can be separated from other alkaline earth ions (10 times magnesium does not interfere) using this reagent. The precipitate is conveniently dried by drawing filtered air through the precipitate on a fritted glass filter; it cannot be oven dried.

Picrolonic acid forms insoluble compounds with copper, lead, potassium, and thorium. It is advantageous in the case of lead because the resulting conversion factor is favorable. To separate lead from interfering ions, it is precipitated with thiourea at 0 C., redissolved, and then precipitated with picrolonic acid.

The Use of Organic Solvents in Metal Analysis

C. J. Rodden, National Bureau of Standards, Washington, D. C.

Solvent extraction has long been used for detecting iodine by means of chloroform. From the quantitative point of view, ethyl ether serves to separate thal-

Speakers and Committee Officers at Symposium—Left to Right: C. J. Rodden, National Bureau of Standards; John F. Flagg, General Electric Co.; S. E. Q. Ashley, General Electric Co.; J. W. Stillman, E. I. du Pont de Nemours and Co., Inc.; G. Frederick Smith, University of Illinois; John H. Yoe, University of Virginia.

lium, iron, arsenic, germanium, and gold as the chlorides. The concentration of chloride is very important as is shown by the fact that iron is not extracted when the concentration of hydrochloric acid is low. Isopropyl ether has been suggested as a substitute for ethyl ether. Best results on these extractions are obtained when some kind of continuous extractor is used. Other inorganic compounds which can be extracted with organic solvents are the thiocyanates of molybdenum, iron, and cobalt, and chromic acid as a complex peroxy compound.

Many metals can be separated by extraction after they have been converted to complex organic compounds. Thus the cupferron complex of uranium can be separated from many interfering substances by means of chloroform. Chelate compounds of metals with 8-hydroxyquinoline are soluble in chloroform and some of the resulting compounds (aluminum and gallium) fluoresce in ultraviolet light.

The dithizone complex compounds are well known and much used for making quantitative separations by extraction with chloroform. The solubility of the dithizonates can be regulated by controlling the pH of the water layer, and adding suitable complex forming reagents such as chloride, iodide, and cyanide.

Other metallic organic precipitates which can be extracted are the compounds of α-nitroso-β-naphthol, of diphenyl carbazide, and of salicylic acid.

Solvent extraction methods have found wide use in connection with the analysis of uranium and they can be used a great deal more widely in connection with the analysis of other metals than has been done in the past.

Organic Reagents in Colorimetric Analysis

John H. Yoe, University of Virginia, Charlottesville, Va.

More than 5000 organic compounds have been investigated in a comprehensive study of possible colorimetric reagents now being made by a group of educational institutions in the South. It has been the aim to chart the behavior of various kinds of organic compounds with all metals in the periodic table under both acid and alkaline conditions. A frequency table of the useful reactions of organic reagents has been drawn up for more than 600 of the 5000 compounds, and it turns out that the transition elements are high in the list of those which form useful colored compounds.

A systematic method of studying the usefulness of an organic reagent is followed. For the reagent, suitable solvents must be found in which the reagent is soluble and stable. The color reaction is then studied as follows:

1. Effect of pH on stability and color of the compounds.
2. Stability of the compounds to light.
3. Nature of the color reaction.
4. Role of color formation.
5. Behavior as to conformity of the Lambert-Beer law.
6. Sensitivity of the color reaction.
7. Optimum concentration range.
8. Effect of the presence of foreign ions.
9. Temperature effects between 15 and 35 C. on the color.

Several examples of studies were discussed. It was found that *p*-nitrosoaniline was quite specific in its color reaction with palladium. By systematic substitution into the organic molecule, it was found that other compounds gave good color reactions so long as the nitro group was in the para position. Some of these compounds were superior to others with regard to the systematic studies listed above and it is possible to pick the best reagent for use under different working conditions.

It was pointed out that almost too many reagents have been found for iron; nearly 25 per cent of the 5000 compounds studied react (without oxidation or reduction) with this ion. An interesting reaction is that of iron with disodium-1,2-dihydroxybenzene-2,5 disulfonate. Three complex compounds are formed between ferric ion and this compound: (1) a blue complex formed in the pH range 4.0 to 4.9, (2) a violet complex formed in the pH range 5.6 to 6.9, and (3) a red complex formed in the pH range 7.2 to 9.4. The red and blue complex compounds both obey the Lambert-Beer law, but the red complex is more sensitive for the determination of iron. The red complex compound can be used as an acid-base indicator in the pH range 7 to 9. Very few inorganic ions interfere with the determination of iron by this method. Titanium forms a stable yellow colored compound which does not interfere with the determination of iron and it is possible to determine titanium in the presence of iron by reducing the iron with hyposulfurous acid.

Organic Reagents for Volumetric Analysis

John F. Flagg, General Electric Co., Schenectady, N. Y.

Organic reagents are used in two ways as volumetric reagents for determining metals:

1. Standardized solutions of the reagents are used to react directly with the metals with some means of detecting the equivalence point in the titration.
2. The metals are precipitated with excess of organic reagent, the precipitate is filtered, washed, and the organic part of the complex metal compound is determined.

An example of the first procedure is that of the amperometric titration of cobalt with α-nitroso-β-naphthol. The cobalt solution is buffered to a pH of 4.5 to 5.0 and titrated directly with a standardized solution of the reagent. At a potential of -1.5 v. (relative to a saturated calomel electrode) the current decreases in a linear fashion as the reagent is added, until the cobalt is entirely precipitated. Further additions of the reagent produce increasing currents and the intersection of the two lines (milliliters of reagent plotted against current) gives the equivalence point. In cases where easily reducible ions are present in the solution it is advantageous to use a potential of about -0.06 v. In this case the current remains constant until the end point is reached, after which it increases with the further addition of the reagent. The method is precise and accurate to within 0.5 per cent of the amount of cobalt present and can be used in the range of 1.5 to 12 mg. of cobalt.

Other examples of direct volumetric methods using amperometric titrations are (1) titration of nickel with dimethylglyoxime; (2) titration of copper with α-benzoinoxime.

The equivalence point in these titrations can be determined conductometrically. For example, if a standardized solution of cupferron is added to a copper solution, the conductivity of the solution increases as the reagent is added because ammonium ions are liberated. After the copper has all precipitated, the conductivity decreases with the addition of reagent because hydrogen ions are then being removed from the solutions. The intersection of the two straight lines (ml. of reagent plotted against conductivity) corresponds to the equivalence point. This method is rapid, the acid concentration is not critical, but iron interferes because it forms a precipitate with cupferron. It has been reported that nickel can be titrated conductometrically with dimethylglyoxime.

Most of the indirect titration methods depend upon the bromination of the organic part of the metal-complex compound. Copper can be precipitated with anthranilic acid, filtered, washed, and dissolved in dilute hydrochloric acid. A standardized bromine solution (from potassium bromate) is added and the excess of reagent back titrated iodometrically. One of the advantages of these bromination methods is the favorable stoichiometric factors which result. When copper is precipitated with salicylaldoxime, the equivalent weight of copper is one fourteenth of its atomic weight; when nickel is precipitated with dimethylglyoxime, and the precipitate titrated with bromine, the equivalent weight of nickel is one twenty-fourth of its atomic weight.

The organic part of a metal complex can be titrated with standardized cerate solutions, although sometimes the course of the reactions is not known. In the case of the oxine complex with magnesium, the reaction is reproducible and one mole of oxine is equivalent to 30 equivalents of cerate ion, so that the equivalent weight of magnesium is one sixtieth of its atomic weight. A disadvantage of this method for magnesium is the fact that blanks will often run high and they must always be determined.

It seems likely that volumetric determinations of metals with organic reagents will be used more extensively in the future because in many cases they offer distinct advantages over other methods used at the present time.

Oxidation-Reduction Indicators

G. Frederick Smith, University of Illinois, Champaign, Ill.

The ferroin type of heterocyclic organic compounds (1,10-phenanthroline, 2,2′-bipyridyl, 2,2′,2″-terpyridyl) were synthesized 45 years before chemists became aware of their usefulness in chemical analysis. The following divalent metal ions form complex compounds:

Iron*	Manganese
Ruthenium*	Beryllium
Osmium	Copper
Cobalt*	Cadmium
Nickel	Silver
Zinc	Chromium*

* Complex compound is colored.

The organic compounds themselves have been used as (1) oxidation-reduction indicators, (2) color "detectives," (3) masking reagents, and (4) anion precipitants.

The most important use of the ferroin compounds is that of oxidation-reduction indicators. Usually the ferrous complexes are used for this purpose. By introducing suitable molecular groups into the more simple ferroin compounds, it is possible to obtain oxidation-reduction indicators which are color sensitive to quite narrow voltage changes between the limits of 0.85 and 1.25 v. (referred to the hydrogen electrode). It is important to remember that the color intensity of the oxidized form of these indicators is not great so that approximately 90 per cent of the indicator must be oxidized to give a visual color change.

As an example of how important it is to pick the right indicator, it was pointed out that chromate ions can be titrated with ferrous solutions using 1,10-phenanthroline as the indicator. For the reverse titrations (ferrous ions with dichromate solutions) 4,4′-dimethyl bipyridyl is superior to any indicator now in use. The reason for this lies in the fact that each indicator changes color at the potential corresponding to the equivalence point for that titration.

The oxidation-reduction of cerate solutions depends a great deal upon the kind of acid present in the solution and upon its concentration. Perchloric acid gives the largent oxidizing potential, and it is possible to titrate 0.001 *N* ferrous solutions with dilute standard cerate solutions using 5-nitro-1,10-phenanthroline as the indicator.

Books Exhibited at the Symposium

A FEATURE of the symposium which attracted considerable attention was an exhibit of some forty publications (55 separate volumes) on organic reagents for chemical analysis of metals, or on related subjects. While the exhibit admittedly did not include all of the worth-while books on the subject, many of the most valuable reference books will be found in the following list of the books exhibited and their suppliers:

(1) Adams, Bachman, Fieser, Johnson, and Snyder, "Organic Reactions," John Wiley & Sons, Inc. (2 volumes).
(2) F. Bamford, "Poisons—Their Isolation and Identification," The Blakiston Company.
(3) W. R. Brode, "Chemical Spectroscopy," John Wiley & Sons, Inc.
(4) E. M. Chamot and C. W. Mason, "Handbook of Chemical Microscopy," John Wiley & Sons, Inc. (2 volumes).
(5) V. G. Dethier, "Chemical Insect Attractants and Repellants," The Blakiston Company.
(6) F. Feigl, "Specific and Special Reactions," Interscience Publishers, Inc.
(7) F. Feigl, "Qualitative Analysis by Spot Tests," Interscience Publishers, Inc.
(8) J. F. Flagg, "Organic Reagents Used in Gravimetric and Volumetric Analysis," Interscience Publishers, Inc.
(9) T. R. P. Gibb, "Optical Methods of Chemical Analysis," McGraw-Hill Book Co., Inc.
(10) M. Goldberg, "English-Spanish Chemical and Medical Dictionary," McGraw-Hill Book Co., Inc.
(11) J. Grant, "Hackh's Chemical Dictionary," The Blakiston Company.
(12) R. C. Griffin, "Technical Methods of Analysis," McGraw-Hill Book Co., Inc.
(13) P. H. Groggins, "Unit Processes in Organic Synthesis," McGraw-Hill Book Co., Inc.
(14) Hawk, Oser, and Summerson, "Practical Physiological Chemistry," The Blakiston Company.
(15) W. J. Hickinbottom, "Reactions of Organic Compounds," Longmans, Green, and Co., Inc.
(16) G. A. Hill and L. Kelley, "Organic Chemistry," The Blakiston Company.
(17) W. F. Hillebrand and G. E. F. Lundell, "Applied Inorganic Analysis," John Wiley & Sons, Inc.
(18) Hober, Hitchcock, Bateman, Goddard, and Fenn, "Physical Chemistry of Cells and Tissues," The Blakiston Company.
(19) Hopkin and Williams, "Organic Reagents for Organic Analysis," Chemical Publishing Co.
(20) E. H. Huntress and L. P. Mulliken, "Identification of Pure Organic Compounds," John Wiley & Sons, Inc.
(21) O. Kamm, "Qualitative Organic Analysis," John Wiley & Sons, Inc.
(22) I. M. Kolthoff and H. A. Laitenen, "pH and Electro Titrations," John Wiley & Sons, Inc.
(23) G. E. F. Lundell and J. I. Hoffman, "Chemical Analysis of Iron and Steel," John Wiley & Sons, Inc.
(24) G. E. F. Lundell and J. I. Hoffman, "Outlines of Methods of Chemical Analysis," John Wiley & Sons, Inc.
(25) I. Mellan, "Organic Reagents in Inorganic Analysis," The Blakiston Company.
(26) M. G. Mellon, "Colorimetry for Chemists," G. Frederick Smith Chemical Co.
(27) A. A. Morton, "Laboratory Techniques in Organic Chemistry," McGraw-Hill Book Co., Inc.
(28) J. B. Niederl and V. Niederl, "Organic Quantitative Analysis," John Wiley & Sons, Inc.
(29) J. H. Perry, "Chemical Engineer's Handbook," McGraw-Hill Book Co., Inc.
(30) F. Pregl, "Quantitative Organic Microanalysis," The Blakiston Company.
(31) F. Schneider, "Qualitative Organic Microanalysis," John Wiley & Sons, Inc.
(32) R. L. Shriner and R. C. Fuson, "The Systematic Identification of Organic Compounds," John Wiley & Sons, Inc.
(33) G. F. Smith and F. P. Richter, "Phenanthroline and Substituted Phenanthroline Indicators," G. Frederick Smith Chemical Co.
(34) F. D. Snell and F. M. Biffen, "Commercial Methods of Analysis," McGraw-Hill Book Co., Inc.
(35) F. P. Treadwell and W. T. Hall, "Analytical Chemistry," John Wiley & Sons., Inc. (2 volumes).
(36) E. Wertheim, "Textbook of Organic Chemistry," The Blakiston Company.
(37) T. I. Williams, "Introduction to Chromatography," Chemical Publishing Co.
(38) J. H. Yoe, "Photometric Chemical Analysis," John Wiley & Sons, Inc. (2 volumes).
(39) J. H. Yoe and L. A. Sarver, "Organic Analytical Reagents," John Wiley & Sons, Inc.
(40) "Allen's Commercial Organic Analysis," The Blakiston Company (10 volumes).
(41) "A New Notation and Enumeration System for Organic Compounds," Longmans, Green, and Co., Inc.

Proposed Method for the Sampling of Steam

A.S.T.M. Committee D-19 on Water for Industrial Uses and the Power Test Code Committee of The American Society of Mechanical Engineers through its PTC Committee No. 19 on Instruments and Apparatus are currently cooperating to develop a Method for the Sampling of Steam and to coordinate A.S.T.M. and A.S.M.E. views on this important subject. Committee D-19 is offering the following proposed method which includes certain fundamental concepts as they refer to the sampling of steam, particularly in respect to a new design of sampling nozzle. Steam condensate sample secured by the use of this method will be available for test to determine the impurities in steam either by a chemical or preferably by an electrical conductance method. The latter method for detecting impurities has been used in recent years and to a large extent has replaced the calorimeter method for the determination of steam quality which was developed by A.S.M.E. However, the proposed A.S.T.M. method, it will be noted, can be used for sampling when a colorimeter is employed.

The proposed method will be particularly useful in connection with the sampling prerequisite to the efficient use of the Proposed Method for Determination of Total Solids in Industrial Waters of High Purity published with the report of Committee D-19 for 1947.

The proposed method given below has been worked out during the past year with cooperation from A.S.M.E. representatives, and arrangements have been made to set up a joint committee to effectuate a coordination of the methods developed by the two societies. The method is being published in the Bulletin so that all who are interested will have an opportunity to review it and be in a position to offer constructive comment thereon at the next meeting of Committee D-19 which will be in Detroit during the A.S.T.M. annual meeting there in June.

Max Hecht of Pittsburgh is the chairman of Committee D-19 and W. A. Carter of the Detroit Edison Co. is chairman of PTC Committee No. 19, while the active work in writing this proposed method was carried out under the direction of B. J. Cross of Combustion Engineering Co., Inc., chairman of the Section on the Sampling of Steam of Committee D-19 and also A.S.M.E. representative on the Committee.

Proposed Method for Sampling of Steam[1]

This is a proposed method and is published as information only. Comments are solicited and should be addressed to the Society, 1916 Race St., Philadelphia 3, Pa.

Scope

1. This method covers the sampling of steam, either saturated or superheated, flowing in a pipe or conduit at a pressure above that of the atmosphere. The only limitation in the application of this method is set by the requirement that the steam being sampled shall be under sufficient pressure to establish the required rate of flow through the sampling nozzle.

Description of Term

2. The term "sampling" in this method shall mean the withdrawal of a representative portion of the steam flowing in the conduit and the delivery of this portion of steam in suitable form to an apparatus for analysis or to a container in which the sample may be preserved for subsequent analysis.

General Principles of Sampling

3. (*a*) The impurities in steam may be solid, liquid, or gaseous. Gaseous impurities may consist of carbon dioxide, oxygen, ammonia, hydrogen, and other gases that may be introduced into the boiler with the feedwater or that may be generated within the boiler. Gaseous impurities may also include the vapor phase of salts present in the boiler water. Gaseous impurities are molecularly dispersed with the steam and do not present a problem in sampling.

(*b*) Solid and liquid impurities consist of dusts and mists that are mechanically entrained in the steam. They are of higher density than the steam and may not be uniformly dispersed. The sampling of such a mixture requires special considerations.

(*c*) One important requirement of the sampling of fluid streams carrying particles in suspension is that the velocity entering the parts of the sampling nozzle shall be the same as the velocity in the stream that is being sampled. A second requirement is that each port of a multiport sampling nozzle shall withdraw a portion of the main stream equivalent to the area of the portion of the pipe or duct in which it is located. This requires, for equally spaced ports, that the size of the port shall be proportional to the fractional area represented, or for equal size of ports, that the spacing must be adjusted so that each port withdraws equal portions of the sample from equal areas of pipe or duct section.

(*d*) The velocity of sample flow within the nozzle should be kept low in order to reduce the pressure drop along the nozzle and to provide as closely as possible, an equal pressure drop across each sampling port. For this reason the total area of the sampling ports should not be more than two thirds of the inside cross-sectional area of the nozzle.

Apparatus

4. The necessary apparatus for the sampling of steam consists of the steam sampling nozzle, the piping and necessary valves and fittings, and, when required, a sample condenser and cooler.

5. *Sampling Nozzle.*—(*a*) The recommended form of sampling nozzle is shown in Fig. 1. This nozzle consists of a piece of pipe or tube inserted through the pipe wall (Note 1) and extending across the pipe on a diameter to within 1/4 in. of the opposite wall. It shall be provided with holes or sampling ports facing upstream (Note 2) in the pipe and so spaced that each port represents an equal area of pipe section. The number of sampling ports shall vary according to the internal diameter of the pipe or tube as follows:

Actual Inside Diameter, in.	Number of Ports
2 to 6	4
Over 6 to 12	6
Over 12	8

The size of the sampling ports shall be such that the ratio of their total area to the area of the pipe is equal to the ratio of the rate of stream flow to the rate of sample flow (Notes 3 and 4). Under this condition the velocity of steam entering the sampling ports will be that of the steam flowing in the pipe.

Note 1.—The portion, *A*, Fig. 1, of the nozzle exposed within the pipe is reduced in diameter so that it may be inserted through the tapped hole in the pipe.

Note 2.—A witness mark should be placed on the external extension of the sampling nozzle so that sampling ports may be correctly directed facing upstream. As it is difficult to properly tighten the threaded nipple and at the same time secure the proper position of the ports, the latter objective should be the first con-

[1] This proposed method is under the jurisdiction of the A.S.T.M. Committee D-19 on Water for Industrial Purposes. Published as information, March, 1948.

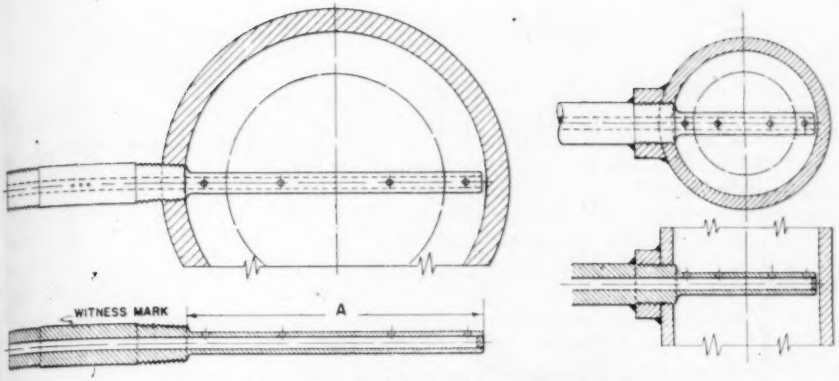


Fig. 1.—Recommended Form of Sampling Nozzle.

Fig. 2.—Sampling Nozzle for Use in Small Tubes.

sideration. The nozzle then may be seal welded to the pipe for tightness.

NOTE 3.—When the sample is analyzed for moisture content by throttling or separating calorimeters, the rate of sample flow is fixed by the characteristics of the calorimeter. The sampling nozzle can be designed for only one rate of flow of the stream being sampled.

NOTE 4.—When the sample is to be condensed or cooled for specific conductance measurements or for the evaporative method of analysis, the sampling nozzle can be designed for maximum rate of stream flow and the rate of sample flow may be adjusted for lower rates of stream flow.

(*b*) The material of the sampling nozzle may be carbon steel for saturated steam. For superheated steam, the material of the nozzle should be of alloy steel at least as stable under the conditions of service as the material of the pipe.

(*c*) The sampling nozzle should be located after a run of straight pipe of a length equal to at least ten diameters. Locations in the order of their preference are:

(1) Vertical pipe, downward flow,
(2) Vertical pipe, upward flow,
(3) Horizontal pipe, vertical insertion, and
(4) Horizontal pipe, horizontal insertion.

The sampling nozzle should not be located immediately after valves or bends. When a boiler is arranged with multiple tubular connections from the drum to a superheater header, samples should be taken in selected tubes spaced across the width of the drum (Notes 5 and 6). Such sampling points should be at no greater than 5-ft. intervals.

NOTE 5.—A sampling nozzle for use in small tubes is shown in Fig. 2. This particular nozzle is for installation in a 3-in. tube (2.6 in. in inside diameter) carrying 20,000 lb. per hr. of steam at 1500 psi. The tube area is 5.31 sq. in. and the sampling port area is 0.0278 sq. in. (four $\frac{3}{32}$ in. holes). The sampling rate should be 108 lb. per hr.

NOTE 6.—Samples may be taken at the inlet header of the superheater. A sampling nozzle suitable for such a location is shown in Fig. 3. As the direction of flow within the header is indeterminate, the inlet ports of this sampler are arranged in a spiral path along the nozzle. The maximum practical length of such a sampling nozzle is 12 ft. For long headers, samplers should be installed at each end of the header. Reliance should not be placed on samples so taken until they are proved by samples taken in connecting tubes according to the recommended procedure.

NOTE 7.—As a guide in the determination of the proportions of the sampling nozzles, reference may be made to Figs. 4 to 7.

6. *Valves, Pipe, and Fittings.*—(*a*) The shortest possible connection shall be made between the sampling nozzle and calorimeter or cooling coil.

NOTE—In the sampling of steam it should be kept in mind that the steam and condensate will dissolve to some degree any substance with which it comes into contact. For this reason the area of surfaces exposed to the sample and the time that the sample is in contact with these surfaces should be kept at a minimum.

(*b*) For use with a colorimeter,[2] the valves, connecting piping, and fittings shall be of carbon steel of suitable schedule as specified in the A.S.M.E. Code.[3]

(*c*) When the sample is to be condensed or cooled, all connecting piping and fittings between the sampling nozzle and condenser shall be of stainless steel at least as resistant to reaction with the steam as 18 per cent chromium, 8 per cent nickel steel.[4]

7. *Condensing and Cooling Coil.*—When the sample is to be condensed and cooled, a tubular heat exchanger of one of several available types may be used. The common requirements of such condensers are as follows:

(*1*) The tube through which the sample flows shall be made of stainless steel at least as resistant to reaction with the steam as 18 per cent chromium, 8 per cent nickel steel.[4]

(*2*) This tube shall be continuous and

[2] A.S.M.E. Power Test Code 19.11 (1940).
[3] American Standard Code for Pressure Piping (ASA No.: B31.1-1942); with 1944 and 1947 Supplements.
[4] A suitable steel for this purpose is type 316, grade M, of the Standard Specifications for Corrosion-Resisting Chromium and Chromium-Nickel Steel Plate, Sheet, and Strip for Fusion-Welded Unfired Pressure Vessels (A.S.T.M. Designation: A 240), 1946 Book of A.S.T.M. Standards, Part I-A. Alternate materials are nickel or monel metal.

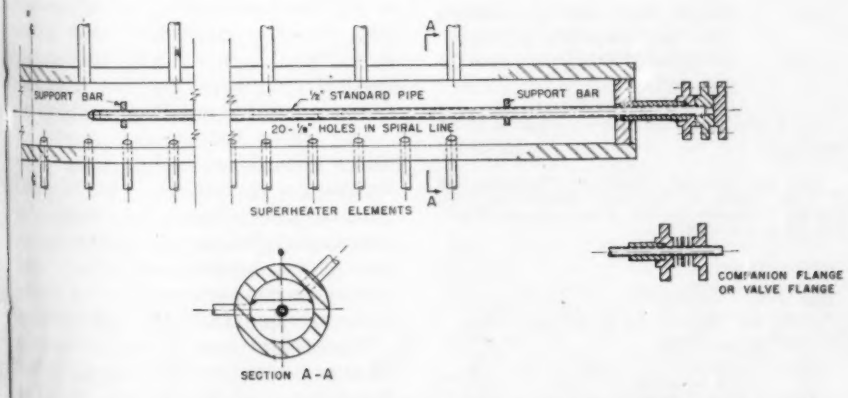


Fig. 3.—Sampling Nozzle for Use in Inlet Header of Superheater.

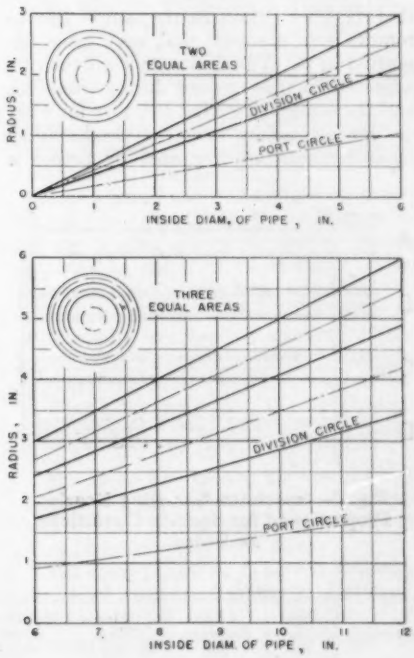


Fig. 4.—Radii of Circles for Dividing a Circular Pipe into Annuli of Equal Areas.

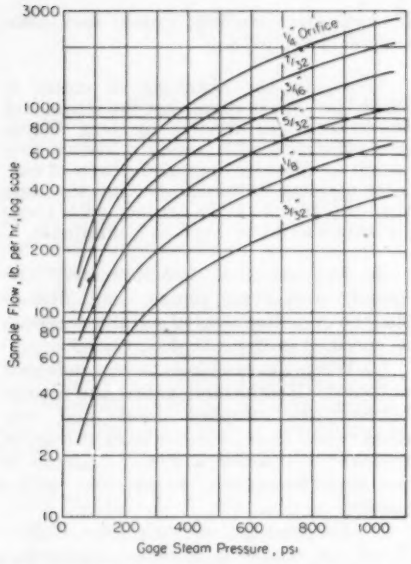


Fig. 5.—Rates of Steam Flow Through Calorimeter Orifices at Different Pressures.

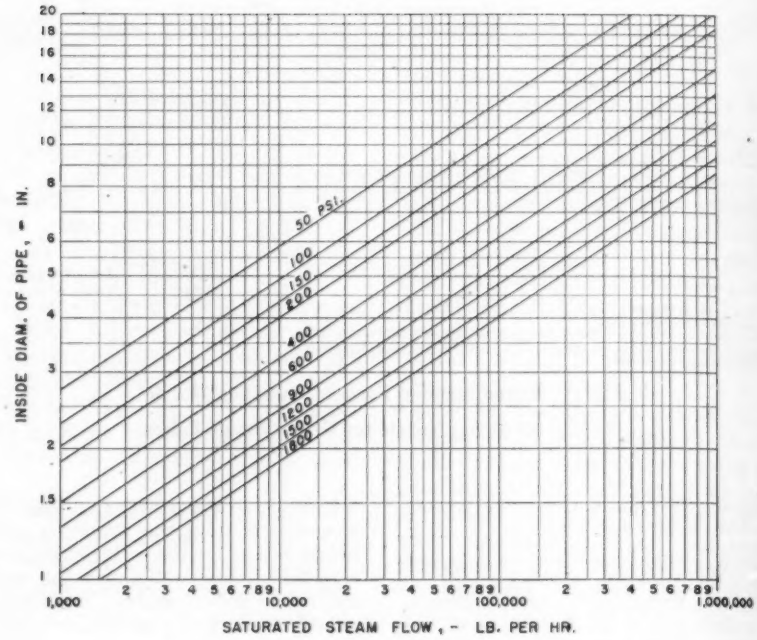


Fig. 6.—Approximate Rates of Flow for Saturated Steam for Different Pipe Internal Diameters at Different Pressures.

shall extend through the cooling jacket so that there will be no danger of contamination of the sample by the cooling water.

(3) The tube shall be of sufficient strength to withstand the full pressure of the steam being sampled.

(4) The tube diameter shall be such that storage within the coil is low and the time lag of sample through the condenser will be a minimum.

Procedure

8. (*a*) When a new sample line is being put into service, steam and condensate shall be flowed through it for 24 hr. before samples are collected.

(*b*) Before a sampling period, steam shall be blown through the sample line to remove any material that may have deposited in it. The flow rate shall then be adjusted to that desired during sampling and the sample flowed at this rate for 1 hr. or longer before electric conductivity measurements are recorded or before a sample is collected for other methods of analysis.

NOTE 1.—When samples are collected for evaporative analysis, the flasks or other types of containers should be meticulously cleaned before using. Pyrex glass is a satisfactory material for such containers but they should be aged by allowing them to stand for several days full of distilled water. This aging of pyrex may be hastened by a preliminary treatment with dilute caustic soda. Metal containers also may be used.[5]

NOTE 2.—Samples should be analyzed as soon as possible after collection. After use, the flasks should be rinsed with hydrochloric acid (1:1). These flasks should be reserved and used for no other purpose than steam samples.

(*c*) The rate of sample flow shall be between 30 and 300 lb. per hr. This sampling rate is determined by the relation:

$$f = a/A \times F$$

where:

f and F = sample flow rate and stream flow rate respectively, and
a/A = the ratio of total port area to pipe area.

(*d*) When the condensed sample is to be analyzed by the electrical conductivity method, it shall be cooled to 25 C. or within the range of the temperature compensation of the instrument used.

(*e*) When the determination of dissolved gases is a consideration, the sample shall be cooled to 20 C.[6]

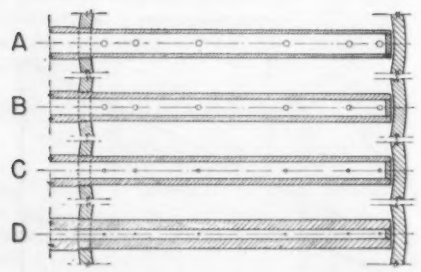


Fig. 7—Specimen Sampling Nozzles Proportioned for Specific Conditions as Noted.

[5] See the Proposed Method for Determination of Total Solids in Industrial Waters of High Purity, *Proceedings*, Am. Soc. Testing Mats., Vol. 47, p. 417 (1947).

[6] See the Tentative Methods of Test for Dissolved Oxygen in Industrial Waters (A.S.T.M. Designation: D 888), 1946 Book of A.S.T.M. Standards, Part III-A, p. 1020.

Nozzle	Pipe Size, in.	Gage Pressure, psi.	Line Flow, lb. per hr.	Numberof Sample Points	Size of Sample Points, in.	Size of Sample Nozzle	$\frac{a}{A} \times 1000$	Sample Flow, lb. per hr.
A.....	8	50	25 000	6	$\frac{11}{64}$	¼-in X	2.77	69
B.....	8	200	77 000	6	$\frac{1}{8}$	¼-in seamless	1.46	143
C.....	8	600	225 000	6	$\frac{9}{64}$	¼-in. seamless	0.571	129
D.....	8	1500	620 000	6	$\frac{7}{16}$	¼-in. XX	0.368	228

Standard Welding Symbols

THE American Welding Society has issued a new publication giving "Standard Welding Symbols and Rules for Their Use." This supersedes an earlier edition and covers some 34 processes used in various industries throughout the country.

In the 1947 standard the method of presentation has been revised from a form of rules, as presented in the 1942 standard, to a step-by-step presentation in lecture-type form. In addition to the improved method of presentation, the rules have been expanded to include a means of indicating welds having root penetration. Other features are the dropping of the confusing terms "near side" and "far side" from the nomenclature, the addition of 45 illustrations showing the various applications of the symbols, and a chart which provides a compact summary of the use of the welding symbols for ready reference.

Copies of this booklet aggregating about 70 pages can be procured from the A.W.S. Headquarters, 33 West 39th St., New York 18, N. Y., at 50 cents.

International Standardization

WITH the Society interested broadly in various aspects of standardization, it is not only natural but essential that the officers of the Society and of many of its technical committees should be alert to the implications of international standards activities. A.S.T.M. contributed to such work as was done both in the International Association for Testing Materials and the International Standards Association, and it has endeavored to maintain friendly contacts and to aid the standardizing bodies of many other countries. As in most international projects or activities, there are many phases and facets, and some of these are noted in a recent discussion by Cyril Ainsworth, Technical Director and Assistant Secretary of the American Standards Association. Mr. Ainsworth has followed international activities closely and it is believed that the A.S.T.M. members who should be and are concerned with international problems might well review the comments by Mr. Ainsworth published in the November-December issue of *Industrial Standardization*.

International Cooperation by Industry

"DURING the past few months the American Standards Association has been flooded with documents indicating that international cooperation on standardization is going forward in full force. Before the war American industry participated in international standardization work only to a limited extent. Now the question is: Does American industry want to participate in this postwar international effort?

"The new projects being proposed should be examined carefully and from a long-range viewpoint. They should be sound in their conception. If not so conceived, American industry might lend its influence in this direction and thus make possible intelligent participation.

"Participation, however, cannot be confined to joining a committee or writing letters. To be effective, it must include the sending of qualified technicians to take part in committee meetings in Europe, since European countries do not have sufficient funds to send representatives to the United States. This kind of participation will require money. If industry is willing to give its financial backing as well as its technical skill to this program, however, in my opinion it will receive a worthwhile return for every dollar it puts into it.

"At the present time American industry is working as hard as it can to meet the demand for goods throughout the world. There is little need to worry about restrictions due to differences in requirements. In a few years, however, other countries may be in a position to buy from the United States on the basis of the specifications they have established. Unless American industry has been taking part in the development of these specifications, the profit margin may be seriously affected or the sale of goods made difficult. Already, an American industry faces heavy cuts in production because one country has placed taxes on its products so heavy that it cannot sell there. A similar situation can arise, not due to taxes but to standards, if the other countries of the world band themselves together and develop requirements which do not conform to American Standards and which thus bar American products.

"An example in reverse is the standard for V-belts which has been tentatively adopted by Norway, Sweden, and Denmark. This proposed standard is in line with American requirements. Before completing this document, the Scandinavian countries first found out what standards existed in the United States. Their new specifications are based on standards of the Society of Automotive Engineers and the Rubber Manufacturers Association obtained through the American Standards Association. The present American program to unify practices in this country can affect not only the Scandinavian proposal but broader international proposals.

"A recommendation for an international project for frozen food packages made by Norway shows the wide implications of this international cooperation. Norway is not interested in buying frozen foods from us. She is, however, interested in buying American refrigeration equipment. Through international agreements on standard sizes, she believes that refrigeration equipment can be purchased from the United States with the assurance that Norwegian frozen food packages will fit satisfactorily in it. The American industry has decided not to participate in this activity for the time being because its own house is not in order. It hopes, however, to keep in touch with it.

"In addition to its opportunity through the committees of the International Organization for Standardization, American industry now has a unique opportunity to register its point of view on standards being developed by countries in the British Commonwealth of Nations. This is a result of action taken at a conference of the National Standards Bodies of the Commonwealth in June of this year. The conference unanimously adopted a procedure whereby a copy of minutes of first meetings of committees and first drafts of standards of the standards bodies of every Commonwealth nation are sent to the United States for review. The American Standards Association circulates these drafts to the industries concerned for comment and criticism. Up to the present time, American industry has not seemed to recognize the significance of this opportunity and the A.S.A. has received very little comment to send back. A few companies, on the other hand, have been very much interested.

"These are a few concrete examples of the relationship between this very much alive international activity and American industrial operations. American industry must evaluate these activities as to their importance. If the value is determined to be of real significance, participation technically and financially should commence as soon as possible so that American interest can be expressed in the early deliberations of these international standardization committees."

Group Travel and Program for International Conference on Soil Mechanics and Foundation Engineering

ARRANGEMENTS are now being completed for group travel to the Second International Conference on Soil Mechanics and Foundation Engineering, to be held in Rotterdam, Holland, June 21–29 incl., 1948. At the suggestion of T. K. Huizinga, Secretary of the Conference, travel arrangements are being made through Lissone-Lindeman, 509 Fifth Avenue, New York 17, New York, B. A. Paris, General Manager. This is the official Dutch travel agency.

Group travel can be arranged on United States Lines ships. Travel to Europe will be via a Maritime Commission steamer operated by the U. S. Lines with comfortable accommodations and regular steward service in dining rooms. The ship and sailing date are not yet known. Return travel will be via the S.S. *Washington* sailing from Le Havre, July 9 and arriving in New York, July 16. The approximate round-trip cost from New York to Rotterdam will be $450 per person.

For those who desire, air travel can be arranged from New York to Rotterdam and return. The approximate cost for the round trip travel by air is $650.

The travel agency has agreed to arrange for hotel accommodations in Rotterdam for the period of the meetings, if the Dutch Committee on Organization has not made housing arrangements.

If sixteen or more persons travel in a group by steamer, or by air, the travel agency has agreed to give approximately

six per cent discount on the travel fares. Costs quoted do not include any U. S. taxes applicable. Special arrangements for return at a later date than July 9 can be made by the travel agency.

Applications for group travel may be secured by writing to the Secretary of the U. S. Committee, namely, Professor Howard P. Hall, The Technological Institute, Northwestern University, Evanston, Ill.

Applications for membership in the Conference, which include one copy of the Proceedings, may also be obtained from the Secretary of the U. S. Committee.

A.S.T.M. is participating officially in the Conference having appointed Professors E. J. Kilcawley, Rensselaer, and F. J. Converse, California Inst. of Technology, as delegates.

Program:

A special Bulletin No. 3 has been issued which gives detailed information on the Conference, notes on the daily program and related events. Copies are available from the U. S. Secretary at Northwestern University.

National Bureau of Standards Work

Two recent announcements from the National Bureau of Standards relate to activities which should be of interest to a number of our members. Brief descriptions appear below, with a reference in each case to a source where more detailed information can be obtained.

Double Freezing Point Method for Styrene Purity:

A simple method for the determination of the purity of styrene, particularly adapted to industrial process control, has been developed by Dr. J. F. Masi of the National Bureau of Standards. The method utilizes an empirical equation relating the percentage of styrene by weight in the sample to two freezing points obtained experimentally with specially designed apparatus. One of these freezing points is taken on a part of the original sample while the other is determined from a portion of the sample from which the more volatile hydrocarbon impurities have been removed by evaporating and recondensing the styrene. This procedure, which was devised for the Office of Rubber Reserve, is now in use in all of the Government-controlled plants making GR-S synthetic rubber.

NOTE: More complete details of this method will be found in a paper by Joseph F. Masi and Ruth K. Cheney in the April (1948) issue of *Analytical Chemistry.*

Thermal Decomposition of High Polymers:

A new method[1] for investigating the composition and properties of high polymers has been developed by S. L. Madorsky and Sidney Straus of the National Bureau of Standards in connection with a program for the study of the structure of natural and synthetic rubbers. The procedure consists in the pyrolysis, or thermal decomposition, of the polymer under high vacuum with subsequent separation of the products into gaseous, liquid, and semisolid fractions for analysis.

One of the most effective means for obtaining information on the structure of polymers and copolymers is thermal decomposition of a sample under conditions of molecular distillation in the absence of oxygen or other reactive substances.

The apparatus developed at the Bureau consists essentially of a double-walled cylindrical flask similar to a Dewar flask except that the inner vessel is joined to the outer jacket by a ground-glass joint. The space between the cylinders is evacuated to a pressure of 0.000001 mm. of mercury and is connected, by means of a side arm, to receivers for the various fractions. At the bottom of this space is a small tray on which a thin layer (25 to 50 mg.) of the polymer is heated to between 300 and 400 C. by means of platinum-wire helices encased in short lengths of glass tubing. During pyrolysis the outer wall of the flask is cooled by water flowing through spiral tubing surrounding the vessel.

Liquid air is first placed in the inner cylinder, and the temperature of the sample is then raised to the point of decomposition. All the products of pyrolysis, except those which do not condense at liquid-air temperature, then collect on the inner wall while the more volatile material is allowed to expand into a receiver. This gaseous fraction is analyzed in the mass spectrometer; its weight can then be calculated for volume, pressure, and composition.

[1] For further technical details see "Pyrolytic Fractionation of Polystyrene in a High Vacuum and Mass Spectrometer Analysis of Some of the Fractions," by Samuel L. Madorsky and Sidney Straus, in *Journal of Research*, Nat. Bureau Standards, for May, 1948, and in *Ind. Eng. Chem.*, May, 1948.

Quartermaster Food and Container Institute Forms Committee on Container Research

THE formation of the Committee on Container Research has been announced by Colonel Charles S. Lawrence, Commanding Officer of the Quartermaster Food and Container Institute for the Armed Forces, Chicago, and George Gelman, Technical Director.

The Committee on Container Research will foster scientific research and training which will provide the necessary technical information and trained personnel for the solution of container problems of the Armed Forces. Members of the Committee are Dr. William H. Aiken, Goodyear Rubber Co.; Dr. B. S. Clark, American Can Co.; Dr. James d'A. Clark, Consulting Engineer; Dr. R. C. McKee, Institute of Paper Chemistry; Mr. A. E. Stevenson, Continental Can Co.; and J. H. Toulouse, Owen-Illinois Glass Co. Dr. Toulouse is a prominent member of A.S.T.M. Committee D-10 on Shipping Containers.

The general classification of research problems to be considered by the Committee on Container Research involves movement and storage, climatic effects, analytical procedures, materials, fabrications, and the dissemination of research and development information to industry and government and university laboratories.

A.S.T.M. Cement Tests Used in PCA Seminar

TESTS which have been established by the Society in the field of cement and concrete are being used in a continuing series of seminars recently inaugurated by the Portland Cement Association at its headquarters in Chicago. This course not only covers the manufacture and use of cement, but also merchandising and public education problems. Participating in the first seminar are representatives of member companies and new additions to the staff. The A.S.T.M. tests come into the picture prominently in connection with courses in the testing laboratory.

There is an increasing use of the specifications and tests of the Society not only in the educational field, but in many other applications. There is a continuing stream of correspondence to and from Headquarters in connection with the reprinting of technical papers and reports, abstracting of the material and also the use of A.S.T.M. standards.

All of this is a healthy sign because the results of the Society's intensive work are intended to be used.

Western Society of Engineers and John Crerar Library to Cooperate

THE Western Society of Engineers, in which are quite a number of A.S.T.M. members, and with which the Society has cooperated on a number of matters, particularly meetings, is officially joining with the John Crerar Library, also an A.S.T.M. member for many years, to establish in Chicago an engineering and science center. The W.S.E. is moving its headquarters to the Taylor Building on Randolph Street, which building is owned by the Library, and offices, conference rooms and a meeting auditorium are to be developed. The 20,000-volume library of the Western Society is to be coordinated with the 700,000 volumes of the John Crerar Library. The latter is the world's largest free public library concentrated on science and technology.

New Members to March 2, 1948

The following 141 members were elected from January 10, 1948 to March 2, 1948, making the total membership 6339.

Names are arranged alphabetically—company members first, then individuals

Chicago District

ARMSTRONG PAINT AND VARNISH WORKS, Donald F. Madigan, Head, Industrial Laboratory, 1330 S. Kilbourn Ave., Chicago 23, Ill.

NICHOLS WIRE AND ALUMINUM CO., C. J. Gaspar, Assistant General Sales Manager, 1725 Rockingham Rd., Davenport, Iowa.

BARMACK, B. J., Senior Engineer, Line Design Div., Engineering Dept., Commonwealth Edison Co., 72 W. Adams St., Room 818, Chicago 90, Ill.

BROWNE, FREDERICK L., Chemist, U. S. Forest Products Laboratory, Madison, Wis. For mail: 3546 Lake Mendota Dr., Madison 5, Wis.

HARBAUGH, ROSS L., Chief Chemist, Inland Steel Co., East Chicago, Ind.

HAVELL, RICHARD F., Ceramic Engineer, Northwestern Terra Cotta Corp., 1750 Wrightwood Ave., Chicago 14, Ill.

KELLEY, WILL G., Assistant Chief Electrical Engineer, Commonwealth Edison Co., 72 W. Adams St., Chicago 90, Ill. For mail: 730 Hibbard Rd., Winnetka, Ill.

LA CROSSE PUBLIC LIBRARY, Muriel Fuller, Librarian, Eighth and Main Sts., La Crosse, Wis.

LAUTERBACH, ARTHUR, Sales Engineer, C. J. Tagliabue Manufacturing Co., Inc., 550 Park Ave., Brooklyn, N. Y. For mail: 1120 Merchandise Mart, Chicago 54, Ill.

RAGATZ, E., Chief Chemist, Allen-Bradley Co., 136 W. Greenfield Ave., Milwaukee 4, Wis.

SHANKS, FLETCHER W., Engineer of Materials, Rock Island District, Corps of Engineers, Clock Tower Bldg., Rock Island, Ill.

SLOANE, GEORGE WILLIAM, District Sales Manager, C. J. Tagliabue Manufacturing Co., Inc., 550 Park Ave., Brooklyn 5, N. Y. For mail: 1120 Merchandise Mart, Chicago 54, Ill. [J]*

STUBENVOLL, KURT H., Product Control Manager U. S. Rubber Co., Eau Claire, Wis.

VAN KLEECK, ARTHUR, Chemist, U. S. Forest Products Laboratory, Madison 5, Wis.

WOLFF, ROBERT L., Chief Engineer, Radio Products, Globe Union, Inc., 900 E. Keefe Ave., Milwaukee 1, Wis.

Cleveland District

WEATHERHEAD CO., THE, James F. Connell, Standards Engineer, 300 E. 131st St., Cleveland 8, Ohio.

FLICKINGER, L. C., Chief Chemist, The Youngstown Sheet and Tube Co., Youngstown 1, Ohio.

ROUSH, MILTON S., Chief Chemist, Thompson Products, Inc., 23555 Euclid Ave., Cleveland 17, Ohio.

RODMAN, C. J., 1315 S. Union Ave., Alliance, Ohio.

SMITH, GALE C., U. S. Industrial Chemicals, Inc., Rockefeller Bldg., Cleveland 13, Ohio.

WESTBROOK, LEON R., Professor of Chemistry, Case Institute of Technology, Cleveland, Ohio. For mail: Briar Hill Dr., Solon, Ohio.

Detroit District

BEIERLA, B. J., Chief Metallurgist, E. W. Bliss Co., Toledo Machine and Tool Division, 1420 Hastings St., Toledo 7, Ohio.

CALDWELL, M. R., Assistant Vice-President, Jarvis Division, Doehler-Jarvis Corp., 1501 Paris Ave., Grand Rapids 2, Mich.

CASE, B. C., Field Engineer, Hanson-Van Winkle-Munning Co., Matawan, N. J. For mail: Room 314, 2842 W. Grand Blvd., Detroit 2, Mich.

DOW, DOUGLAS, President and General Manager, The Detroit Testing Laboratory, 554 Bagley Ave., Detroit 26, Mich.

MULLIGAN, MAURICE J., Research Chemist, General Motors Corp., Research Laboratories Division, Box 188, North End Station, Detroit 2, Mich.

SCHAIBLE, JOHN A., Works Manager, Autmotive Aids Corp., 7710 West Warren Ave., Detroit 10, Mich. For mail: 6516 Appoline, Dearborn, Mich.

SZCZERBACKI, STEVE, Instructor, Detroit Institute of Technology, 2020 Witherell, Detroit, Mich. For mail: 7350 Edward St., Detroit 10, Mich.

New England District

BARRE WOOL COMBING CO., LTD., THE, John John M. Gould, Plant Chemist, South Barre, Mass.

JARRELL-ASH CO., R. F. Jarrell, Treasurer, 165 Newbury St., Boston 16, Mass.

ACHORN, D. T., Chief Engineer, Socony-Vacuum Oil Co., Inc., Box 2196, Boston 6, Mass.

FREDERICK, JACOB K., JR., Assistant Professor, Lowell Textile Inst., Lowell, Mass.

LATHAM, EARL, Quality Control Co-Ordinator, The Esmond Mills, Inc., Esmond, R. I.

MAJORS, HARRY, JR., Assistant Professor of Mechanical Engineering, Massachusetts Institute of Technology, 77 Massachusetts Ave., Room 1-212, Cambridge 39, Mass.

PROTZE, HERMAN G., Engineer, Boston, Mass. For mail: 41 Martin Rd., Wellesley 81, Mass.

SINCLAIR, S. E., Chief Metallurgist, Greenfield Tap and Die Corp., Greenfield, Mass.

WELLS, RICHARD D., Director of Quality Control, Bates Manufacturing Co., Laboratory Dept., Box 591, Lewiston, Me.

WHITE, MERIT P., Scientific Consultant, U. S. War Dept., Whately, Mass.

New York District

CIRCLE WIRE AND CABLE CORP., Manuel H. Savage, Chief Chemist, 5500 Maspeth Ave., Maspeth, L. I., N. Y.

GENERAL FOODS CORP., H. L. Stackhouse, Chief Design and Construction Engineer, 250 Park Ave., New York 17, N. Y.

GRAPHITE METALLIZING CORP., Warren W. Walker, President, 1050 Nepperhan Ave., Yonkers 3, N. Y.

HOPPER PRODUCTS, INC., PORTITE DIVISION, Edward T. Campbell, Technical Director, 12 E. Forty-first St., New York 17, N. Y.

MOELLER INSTRUMENT CO., Charles E. Moeller, Jr., Vice-President, 132nd St. and Eighty-minth Ave., Richmond Hill 18, N. Y.

PATENT BUTTON CO., THE, J. V. Petrocelli, Chief Chemist, Box 710, Waterbury 88, Conn.

BARNES, RAYMOND WILLIAM, Specification Engineer, New York City Department of Purchase, Bureau of Standardization, Municipal Bldg., New York 7, N. Y. For mail: 116-40 Park Lane South, Kew Gardens 15, N. Y.

CROFT, WILLIAM HILTON III, Suite 1014, 111 Broadway, New York 6, N. Y. [J]

DOWNING, VINCENT F., Physicist, American Brake Shoe Co., Chemical Lab., Mahwah, N. J.

DE SALVO, FRANK P., Chemical Engineer, Koppers Co., Inc., Kearny, N. J. For mail: 6802 Sixteenth Ave., Brooklyn 4, N. Y.

GEIGER, GEORGE F., Development and Research, The International Nickel Co., Inc., 67 Wall St., New York 5, N. Y.

GERIN, FERNAND L., President, The Gerin Corp., Box 653, Red Bank, N. J.

HIBBARD, WALTER R., Assistant Metallurgist, American Brass Co., Waterbury 88, Conn. For mail: 37 Euclid Ave., Waterbury 30, Conn.

KERR-MUIR, RONALD J., Manager, Lustre Fibres, Ltd., 350 Fifth Ave., New York, N. Y.

KUCERA, G. J., Plant Manager, Reilly Tar and Chemical Corp., 191 Doremus Ave., Newark 5, N. J.

LANDIS, WARREN C., Supervisor, Technical Section, Shell Oil Co., Inc., 50 W. Fiftieth St., New York 20, N. Y.

MAYER, CHARLES A., Assistant Engineer, The Asphalt Inst., 801 Second Ave., 18th Fl., New York 17, N. Y.

MITTENZWEI, EDWIN F., In Charge of Engineering, Lee Spring Co., Inc., 30 Main St., Brooklyn 1, N. Y.

POLLAK, ARTHUR, Consulting Chemical Engineer, 1718 Grand Ave., New York 53, N. Y.

POLYTECHNIC INSTITUTE OF BROOKLYN, DEPARTMENT OF AERONAUTICAL ENGINEERING AND APPLIED MECHANICS, Bruno A. Boley, Assistant Director of Structural Research, 99 Livingston St., Brooklyn 2, N. Y.

PURDY, ALVIN C., President, Bull & Roberts, Inc., 117 Liberty St., New York 6, N. Y.

REISER, CYNTHIA LEE, Research Chemical Engineer, General Chemical Division, Allied Chemical and Dye Corp., Box 149, Long Island City, N. Y. For mail: 39-19 108th St., Corona, N. Y. [J]

REVELLE, WILLIAM, 707 Cooper St., Watertown, N. Y.

ROLL, KEMPTON H., Metallurgist, Lead Industries Assn., 420 Lexington Ave., New York 17, N. Y. [J]

SMITH, HOWARD, N., Textile Technologist, Hesslein and Co., Inc., 77 Worth St., New York 13, N. Y.

STERN, KONRAD, Senior Field Engineer, Barber Asphalt Corp., 485 Madison Ave., New York 22, N. Y. For mail: 1200 State St., Barber, N. J.

STICKNEY, F. S., Instrument Specialties Co., Inc., Little Falls, N. J.

UNITED NATIONS, HEADQUARTERS PLANNING OFFICE, Glenn Bennett, 210 Manhattan Bldg., 405 E. Forty-second St., New York 17, N. Y.

U. S. NAVY SUPPLY CORPS SCHOOL, TEST AND DEVELOPMENT DEPT., C. J. Heinrich, Chief Research Engineer (Bureau of Supplies and Accounts), Bayonne, N. J.

VANDER VALK, CHRISTY J., Technical Director, Red Lead Div., Lead Industries Assn., 420 Lexington Ave., New York 17, N. Y.

VOLK, VICTOR F., Cable Engineer, The Whitney Blake Co., Hamden, Conn. For mail: 230 Chatham St., New Haven 13, Conn.

Northern California District

PACIFIC BRIDGE CO., George W. Noe, 333 Kearny St., San Francisco 8, Calif.

ARMSTRONG, L. S., Chief Engineer, Bank of America, 300 Montgomery St., San Francisco 4, Calif.

LANDIS, ROY G., Director, Oakland Lab., The Sherwin-Williams Co., 1450 Sherwin Ave., Oakland 8, Calii.

Philadelphia District

ASSOCIATED RUBBER, A. N. Shea, Owner, Box 61, Quakertown, Pa.

LANSDALE TUBE CO., William J. Hindman, Chief Chemist, Church Rd., Lansdale, Pa.

SHARPLES CORP., THE, Charles M. Ambler, Process Engineer, 2300 Westmoreland St., Philadelphia 40, Pa.

ALLABACH, EARL P., Consulting Engineer, 1933 Commercial Trust Bldg., Philadelphia 2, Pa.

CAIRNS, THEODORE E., JR., Chemist, Standard Pressed Steel Co., Jenkintown, Pa.

CIAGLIA, A. H., Vice-President and General Manager in Charge of Research, Dumor Plastics, Inc., Atco, N. J.

LEWIS, BRUCE L., Mechanical Engineer, Tinius Olsen Testing Machine Co., 500 N. Twelfth St., Philadelphia 23, Pa.

LINTON, WILLIAM HOWARD, Junior Mechanical Engineer, Birdsboro Steel Foundry and Machine Co., Birdsboro, Pa. For mail: 560 Kohn St., Norristown, Pa.

MERRIMAN, THURSTON C., Consulting Metallurgist, Phosphor Bronze Smelting Co., 2200 Washington Ave., Philadelphia 46, Pa.

RICE, CLAUDE K., Analyst, Gulf Oil Corp., Girard Point, Philadelphia, Pa. For mail: 219 Shirley Rd., Upper Darby, Pa.
SANFORD, EDWARD R., Engineer of Tests, Penn Steel Casting Co., Chester, Pa. For mail: 11 Linden Ave., Rutledge, Pa.
SIMPSON, T. P., Director, Research and Development Dept., Socony-Vacuum Laboratories, Paulsboro, N. J.
SIVERTSEN, JENS, Product Engineer, International Resistance Co., 401 N. Broad St., Philadelphia 8, Pa.
WILEY, JOHN A., Chief Chemist, The Midvale Co., Nicetown, Philadelphia 41, Pa.

Pittsburgh District

BLAW-KNOX CONSTRUCTION CO., CHEMICAL PLANTS DIVISION, G. E. Kopetz, Chief Engineer, Box 778, Pittsburgh 30, Pa.
KOPPERS CO., INC., CHEMICAL DIVISION, Gilbert Thiessen, Development Manager, 2320 Koppers Bldg., Pittsburgh 19, Pa.
PENNSYLVANIA REFINING CO., William E. Harris, Jr., Chemist, Karns City, Pa.
CHANDLER, C. F., JR., Engineer of Tests, Bethlehem Steel Co., Inc., Steelton, Pa.
EYMAN, H. J., Metallurgical Engineer-General, Carnegie-Illinois Steel Corp., Carnegie Bldg., Pittsburgh 30, Pa.
REDMOND, WALTER M., Manager of Inspection, Talon, Inc., 626 Arch St., Meadville, Pa.
THOMAS, ROBERT K., Chief Chemist, Warner Co., Bellefonte Division, Bellefonte, Pa.

St. Louis District

MACELWANE, JAMES B., Dean, St. Louis University, Institute of Geophysical Technology, 3621 Olive St., St. Louis 8, Mo.
MOONEY, THOMAS J., Production Manager, Laclede Steel Co., 1317 Arcade Bldg., St. Louis 1, Mo.
MYERS, JAMES E., Manager, Wichita Chemical and Testing Laboratories, 1111 E. Central, Wichita 7, Kans.
SCHREPFER, A. M., Refinery Superintendent, The Vickers Petroleum Co., Inc., Potwin, Kans.

Southern California District

KLOPSCH, OTTO Z., Works Manager, Phelps Dodge Copper Products Corp., 6100 Garfield Ave., Los Angeles 22, Calif.
WRIGHT, CHARLES C., Seybold & Wright, Consulting Chemists, 7425 Sunset Blvd., Hollywood 46, Calif. For mail: 6631 S. Kingman Ave., Buena Park, Calif.

Washington (D. C.) District

BRITTON, RALPH R., Chief Engineering Adviser, Housing and Home Finance Agency, Technical Staff, Washington 25, D. C.
CONRAD B. K., Engineer of Tests, Atlantic Coast Line Railroad Co., Wilmington, N. C.
FISHER, CLARENCE F., Architectural Engineer, 7302 Massachusetts Ave., Washington 16, D. C.
LLOYD, RICHARD LOUIS, Electrical Safety Engineer, National Bureau of Standards, Washington 25, D. C.
WEBER, CHARLES G., Paper Technologist, National Bureau of Standards, Washington 25, D. C. For mail: 3807 N. Upland St., Arlington, Va.

Western New York-Ontario District

MCDONNELL, MITCHELL J., Chief Inspector, John Inglis Co., Ltd., 14 Strachan Ave., Toronto 1, Ont., Canada.
TOYE, L. G., Metallurgical Engineer, Laboratory, Locomotive and Car Equipment Divs., General Electric Co., Erie Works, East Lake Rd., Erie, Pa.

U. S. and Possessions

COTTON PURCHASING DEPT., DEERING MILLIKEN MILLS, INC., Harry Defore, Director, Cotton Research, Box 337, Union, S. C.
DARLINGTON MANUFACTURING CO., F. P. Mullendore, Assistant to Treasurer, Darlington, S. C.
DRAYTON MILLS, Martin G. Wallace, Jr., Technician, Spartanburg, S. C.
FEN-TER REFINING CO., L. E. Riffe, Technical Director, Kerr-McGee Bldg., Oklahoma City 2, Okla.
BOISSELIER, M. C., Assistant Sales Manager Texas Steel Co., Fort Worth 9, Tex.
DAVIS, L. J., Secretary-Treasurer, Schaefer-Hitchcock Co., Sandpoint, Idaho.
FRANTZREB, JOHN G., Chief Metallurgist, J. D. Adams Manufacturing Co., 217 S. Belmont Ave., Indianapolis 6, Ind.
HILL, J. E., Metallurgical Engineer, Tennessee Coal, Iron and Railroad Co., Birmingham 2, Ala.
HOOD, PERCY E., Resident Manager, Pittsburgh Testing Laboratory, 5190 Scenic Highway, Baton Rouge, La.
LADD, FORREST, Vice-President, John A. Denie Sons Co., 373 Adams, Memphis, Tenn.
MEILER, JOHN G., Director, Plywood Research Foundation, 620 E. Twenty-sixth St., Tacoma 4, Wash.
PASKELL, ERNEST, JR., Engineer, Battelle Memorial Inst., 505 King Ave., Columbus 1, Ohio. [J]
PERKINS, W. C., Chief Engineer, Engineering Dept., Union Pacific Railroad Co., 1416 Dodge St., Omaha 2, Nebr.
PHILPOTT, J. H., Civil-Structural Engineer, 631 N. E. Tenth St., Ft. Lauderdale, Fla. For mail: Box 1493, Ft. Lauderdale, Fla.
PRICE, DONALD L., Carpenter, 4 S. Clarkson St., Denver 9, Colo. [J]
TEXAS ENGINEERS LIBRARY, College Station, Tex.
THOMAS, JOHN M., Technical Director, Resin Division, Jones-Dabney Co., Inc., 1481 S. Eleventh St., Louisville, Ky.
UBBEN, JAMES E., Metallurgist, Emsco Derrick and Equipment Co., 7626 Denton Dr., Dallas, Tex. For mail: Box 7126, Dallas, Tex.
WOODS, W. A. E., Vice-President, Texas Steel Co., Fort Worth 9, Tex.

Other than U. S. Possessions

MINERO METALURGICA DEL ESTANO S. A. E., F. Torras Serratacoo, Manager, Miguel Moya 4, Madrid, Spain.
POLIET & CHAUSSON, 125 Quai de Valmy, Paris 10e, France.
ALI, S. MUMTAZ, Civil Engineer, Government of Orissa (India), Cuttack, Orissa, India. For mail: c/o S. Siddick Ali, P. O. Golmuri, Jamshedpur, Bihar, India [J]
BEATTIE, IRA M., Assistant Professor of Civil Engineering, University of New Brunswick Library, Fredericton, N. B., Canada.
CHENG, C. F., Metallurgical Engineer, The International Nickel Co., Inc., 67 Wall St., New York 5, N. Y. For mail: c/o Imperial Chemical Industries (China) Ltd., 133 Szechuen Rd., Shanghai, China.
DECASTRO, G. L., Chief Chemist, Cia. Cubana de Cemento Portland, Cayo Mason, Cuba.
GIERSING, POUL, Production Manager, Tunnel Portland Cement Co., Ltd., West Thurrock, Essex, England.
GILLI, MARIO P., Vice-President, Sirples, Societa Italiana Importazioni Esportazioni, Corso Venezia 37, Milan, Italy.
HAGGLUND, ERIK HAJIME M:SON, Metallurgical Engineer, In Charge of Laboratory, Aktiebolaget Kanthal, Hallstahammar, Sweden.
MATTSON, NILS, Manager, Linoleum AB Forshaga, Gothenburg, Sweden.
MCLACHLAN, JOHN ARTHUR, Johannesburg City Council, Laboratory Division, Public Health Dept.., Box 1049, Johannesburg, South Africa.
OLSSON, SVEN G., Civilingenior, Grev Turegatan 49i, Stockholm, Sweden.
PAIDASSI, JEAN, Professor of Metallurgy, Universidad de Concepcion, Casilla 169, Concepcion, Chile.
ROBINSON, R. W., General Superintendent of Rolling Stock and Shops Dept., Rio de Janeiro Tramway, Light and Power Co., Ltd., Caixa Postal 571, Rio de Janeiro, Brazil.
SHEARER, R. E. P., Technical Adviser, The New Hindustan Cements, Ltd., 51 Mahatma Gandhi Rd., Bombay 1, India.
SMITH, D. G., Chief Chemist, Anglo-Iranian Oil Co., Ltd., Research Station, Chertsey Rd., Sunbury-on-Thames, England.

* [J] Denotes Junior Member.

Personals . . .

. . .News items concerning the activities of our members will be welcomed for inclusion in this column.

E. R. Murphy, formerly Engineer for the Gypsum Association, Chicago, has been appointed Director of Research for the Vermiculite Research Institute, Evans, Ill., succeeding V. E. Watts.

Frederick D. Rossini, Chief of the Section on Thermochemistry and Hydrocarbons, National Bureau of Standards, has been elected President of the Washington Academy of Sciences, which this year celebrates the fiftieth anniversary of its founding.

J. Bennett Hill, formerly Manager, Development Div. of the Manufacturing Dept., Sun Oil Co., Philadelphia, has been appointed Director of the Chemical and Engineering Division of the Company's recently created Research and Development Dept.

James A. Murray, for many years associated with the Warner Company of Philadelphia as Director of Research, has been appointed Associate Professor of Materials in the Department of Building Engineering and Construction at the Massachusetts Institute of Technology. Professor Murray will take charge of the masonry materials research laboratory, in which fundamental research on cementitious materials and masonry units is being conducted.

F. V. Reagel, Engineer of Materials, Missouri State Highway Department, has been elected Chairman of the Highway Research Board; and **R. A. Moyer,** Research Associate Professor of Highway Engineering, Iowa State College, has been named Vice-Chairman of the Board.

John M. Campbell was recently appointed Head of the Organic Chemistry Department of the Research Laboratories Division, General Motors Corp., Detroit. Mr. Campbell is SAE representative on A.S.T.M. Committee D-2 on Petroleum Products and Lubricants.

W. G. Kelley, Assistant Chief Electrical Engineer of the Commonwealth Edison Co., Chicago, Ill., retired January 31 after more than 46 years' service with his company. Mr. Kelley had been an active member of A.S.T.M Committee A-5 on Corrosion of Iron and Steel since 1931.

Everett S. Lee, Engineer, General Engineering and Consulting Laboratory, General Electric Co., Schenectady, N. Y., is nominee for 1948–1949 President of the American Institute of Electrical Engineers.

Charles A. Marlies, Associate Professor or Chemical Engineering, College of City of New York, and **Joseph Mattiello,** Technical Director, Hilo Varnish Co., were among a group of chemists and chemical engineers recently nominated as fellows of the New York Academy of Science.

Harry E. Outcault was recently appointed Manager, Zinc Oxide Sales, St. Joseph Lead Co., New York City. Mr. Outcault has been associated with the company since 1931, when their new Electro-Thermic zinc oxide plant went into production. He served as Manager of Technical Service and more recently as Assistant Sales Manager. He has represented his company on A.S.T.M. Committee D-11 on Rubber since 1931, and is its present Vice-Chairman. He is also a member of Committee D-1 on Paint.

Foster Dee Snell, President, Foster D. Snell, Inc., is chairman of the general committee planning for the Fall Meeting of the American Oil Chemists' Society in New York City at the Pennsylvania Hotel on November 15, 16, and 17, 1948. This is the first time for over ten years that a meeting of the society has been held in New York City. **J. J. Mattiello,** Technical Director, Hilo Varnish Corp., is vice-chairman of the same committee, and the following are in charge of specific subcommittees: **M. F. Lauro,** Chief Chemist, New York Produce Exchange—Arrangements; **Donald Price,** Technical Director, Oakite Products, Inc.—Finance; **John B. Calkin,** Coordinator of Research, Union Bag and Paper Corp.—Publicity.

William A. Oliver, formerly associate professor, has been named a full professor in the Civil Engineering Department, University of Illinois. Professor Oliver has been giving courses in structural analysis, construction materials, structural design, and estimates and costs.

Jay C. Harris, of Monsanto Chemical Co. Central Research Laboratories, Dayton, Ohio, and Secretary of A.S.T.M. Committee D-12 on Soaps and Other Detergents, was the principal speaker at a recent meeting in Boston of the northern New England section of the American Association of Textile Chemists and Colorists. The subject of his address was "Builders in Detergents."

E. George Stern has been promoted from Associate Research Professor to Research Professor in Wood Construction, and Director, Wood Research Lab., Virginia Polytechnic Institute, Blacksburg.

E. T. Barron, who retired last July as Chief Metallurgical Engineer of Carnegie-Illinois Steel Corp. after 41 years of service with this company, returned from Japan to the United States in December after completing a five-month survey of the iron and steel, chemical, shipbuilding, and oil and power industries for Overseas Consultants, Inc. This independent engineering survey was made on contract with the U. S. War Department.

Harold R. Alley, formerly Director of Rsearch, Arvey Corp., Chicago, Ill., is now Chief Chemist, Mystik Adhesive Prod. Div. of Chicago Show Printing Co.

G. H. Woodroffe is retiring from Baldwin Locomotive Works, Philadelphia, as Assistant Supervisor of Cancellations.

Herbert Albert Sleaco is now Engineer with The Hydro-Electric Power Commission of Ontario, Moor Lake, Canada. He was formerly affiliated with Beaver Hall House, Montreal, in a similar capacity.

George W. DeBell, formerly of Stamford, Conn., and East Chatham, N. Y., is now Factory Manager, Plastic and Die Cast Products Corp., Los Angeles, Calif.

Robert W. Waring is now Assistant Chief Engineer, The Bullard Co., Bridgeport, Conn. He was formerly associated with the Bridgeport Brass Co.

Michael Bock II, previously affiliated with the Unexcelled Chemical Corp., Cambridge, Mass., as Metallurgical Engineer, is now Chief Engineer with Exomet, Inc., Conneaut, Ohio.

Bernice S. Bronner has joined the staff of American Cyanamid Co., New York City. She was formerly affiliated with the American Standards Assn. as Home Economist and Textile Technologist.

Ansel Tucker Rogers has been appointed Manager of Sales Engineering, Lehigh Navigation Coal Co., Inc., Lansford, Pa. He was previously Manager of the North American Cement Corp., New York City.

Bruno Sachs, former Production Manager of Collin Corp., Irvington, N. J., is now associated with Quiet-Heet Mfg. Corp., Newark, N. J.

M. B. Chittick has left his position as Manager of Specialty and Technical Sales, The Pure Oil Co., Chicago, and is now affiliated with American Mineral Spirits Co., New York City.

W. A. Silliman is now Metallurgist with American Metal Treating, Willoughby, Ohio. He was previously associated with The Oliver Corp., Cleveland, in a similar capacity.

Thomas A. Wilson, formerly Senior Fellow, Mellon Institute of Industrial Research, Pittsburgh, Pa., has been appointed Research Chemist, The Clark Thread Co., Newark, N. J.

W. G. Lovell is now Associate Director of Research, Ethyl Corp., Detroit, Mich. He was previously affiliated with General Motors Corp., Detroit.

Gilbert K. Brower has been named Vice-President of Manufacturing, John L. Ray Oil Corp., South Braintree, Mass. He was formerly Chief Materials Engineer, American Airlines, Inc., New York City.

John E. Schulze, previously a member of the firm of Schulze, Limber & Wilshire, Chicago, Ill., is now Senior Partner, The Faresac Co., Dolton, Ill.

Leo J. Waldron, former Corrosion Engineer, Federal Public Housing Authority, has been appointed Corrosion Engineer, Naval Research Laboratory, Washington, D. C.

Albert H. Postle has accepted an appointment with the Sprague Electric Co., North Adams, Mass. He was formerly with Philco Corp., Philadelphia, Pa.

Moses D. Heyman has been named Director of Research, Integrated Mica Corp., Woodmere, N. Y. He was previously associated with the Heyman Co., New York City, in a similar capacity.

B. W. Pelton Colonel, U. S. Army, recently retired from the Quartermaster Corps Inspection Service. He will make his home at Pawling, N. Y.

Donald L. Colwell, widely known to many A.S.T.M. members and active in committee work for many years, particularly in the non-ferrous field, is continuing his contacts with the Apex Smelting Co., which took over the National Smelting Co. In this new company setup his territory has been considerably expanded.

Anthony J. Langhammer, President of the Amplex Division of the Chrysler Corp., Detroit, is the fourth recipient of the annual medal award of the Stevens Institute of Technology for outstanding achievement in the field of powder metallurgy. Presentation was made on Tuesday evening, February 17, when Mr. Langhammer delivered the annual medal lecture on "The Industrial Application of the Powder Metallurgy Process" in the auditorium of the Stevens Administration Building, Hoboken, N. J.

W. R. Brode

W. R. Brode New Associate Director at Bureau of Standards

ANNOUNCEMENT has been received of the appointment of Dr. Wallace R. Brode as Associate Director of the National Bureau of Standards, succeeding Dr. Hugh L. Dryden. An outstanding authority in the field of spectroscopy, Dr. Brode has been Professor of Chemistry at Ohio State University. His undergraduate work was done at Whitman College and he received his master's and doctor's degrees from the University of Illinois. Dr. Brode has been actively interested in the work of A.S.T.M., serving on Committee E-2 on Spectrographic Analysis, and he is the author of a report published by the Society giving information on sources of supply for standards and pure materials.

An article describing the work of the Bureau including several new divisions, together with information on department heads, appeared in the October ASTM BULLETIN.

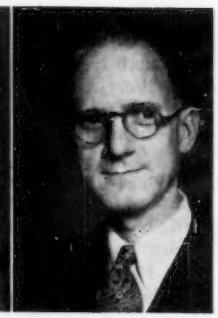
Bureau of Standards Appointments

Two A.S.T.M. members have recently received important appointments in the National Bureau of Standards. Dr. Gordon M. Kline, very active in A.S.T.M. for a number of years, particularly in Committee D-20 on Plastics, and Chief of the Organic Plastics Section at the Bureau since 1935, has been appointed Assistant Chief, Division of Organic and Fibrous Materials. Dr. R. D. Stiehler, with the Bureau since 1946, has been appointed Chief, Testing and Specifications Section, Division of Organic and Fibrous Materials.

Technical editor of *Modern Plastics* for a number of years, Dr. Kline in his new appointment succeeds P. L. Wormeley, who retired at the end of 1947. Dr. Kline is chairman-elect of Committee D-20 on Plastics, and is Vice-Chairman of the newly organized A.S.T.M. Washington District. He has been at the Bureau since 1929. He will continue his activities as Chief of the Organic Plastics Section in addition to his new responsibilities.

Dr. Stiehler, who has been active in the rubber field since 1939, was in charge of the Product Testing and Quality Control Branch of the Office of Rubber Reserve, and did much to establish quality control methods for the synthetic rubber production program.

R. D. Stiehler



G. M. Kline

Robert F. Blanks

Blanks, New President of Concrete Institute

The new President of the American Concrete Institute is Robert F. Blanks of Denver, Chief of Research and Geology for the U. S. Bureau of Reclamation. He succeeds Stanton Walker of Washington, D. C., Director of Engineering for the National Sand and Gravel Association. Both of these men have been very active in A.C.I. work and both are long-time A.S.T.M. members, having participated intensively in numerous A.S.T.M. committee projects, including particularly Committee C-9 on Concrete and Concrete Aggregates, of which Mr. Walker is the current Secretary.

A native of Kansas and a graduate of Kansas State College, Mr. Blanks has done outstanding work in connection with diversified engineering problems in the Bureau of Reclamation's intensive work involving particularly huge dams in the west. He has received many honors and awards from various sources for his activities.

New Director of Westinghouse Research Laboratories

Dr. L. W. Chubb, who has always been interested in the work of A.S.T.M. and has participated in various phases of it, has been named Director Emeritus of Westinghouse Research Laboratories, having retired for reasons of health following an active directorship of 17 years. He is succeeded by Dr. J. A. Hutcheson, who has served as Associate Director for the past four years.

A member of the 1905 class of Ohio State University, Dr. Chubb became associated with Westinghouse immediately after graduation, recently rounding out 40 years of research and engineering with the company. His uninterrupted activity in developments and improvements in a wide variety of fields won him some 150 patents. Especially prominent in the development of new radio equipment, during World War II he served as consultant on numerous committees charged with development of new military equipment and weapons. Last year he was awarded the John Fritz Medal—"for pioneering genius and notable achievement during a long career devoted to the scientific advancement of the production and utilization of electrical energy."

Dr. Hutcheson joined Westinghouse soon after graduation from the University of North Dakota in 1926. Later as a design engineer he specialized on communications equipment, receiving an honorary doctor's degree in 1943 from his Alma Mater in recognition of achievements in radio and electronics engineering. He directed his company's extensive wartime radar research program and subsequent formulation of plans for atomic energy development. With the shift of atomic energy development to peacetime applications, he became chief adviser to a group formed to coordinate and advance all atomic energy research within Westinghouse. He will continue active in both the radar and atomic energy fields.

NECROLOGY

John M. Young, Consulting Engineer and Professor Emeritus of English, University of Hawaii, Honolulu, Hawaii (circa September, 1947). Member since 1908.

John H. Ramage, Metallurgist, Westinghouse Lamp Div., Westinghouse Electric Corp., Bloomfield, N. J. (December 22, 1947). Member since 1936 and Consulting Member of Subcommittee on Metallic Materials for Radio Tubes and Incandescent Lamps of Committee B-4 on Electrical Heating.

Howard W. Gilbert, Engineering Assistant to President, National Malleable and Steel Castings Co., Cleveland, Ohio (January 16, 1948). Representative of company membership since 1920, and representative of his company for many years on Committee A-1 on Steel, and A-7 on Malleable-Iron Castings.

Notes on Laboratory Supplies

Catalogs and Literature; Notes on New or Improved Apparatus

Catalogs and Literature:

Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia 44, Pa. A new seven-page catalog entitled "Micromax Model C Indicating Controllers" has just been issued which presents these instruments for the first time under one cover. This publication lists complete specifications in easy-to-use tabular form for all Model C Controllers—whether they are potentiometers or Wheatstone bridges; whether they measure temperature through the use of thermocouples, Rayotubes or Thermohms; whether they provide two-position control or Micromax Electric Control—either position-adjusting type for fuel-fired furnaces or duration-adjusting type for electrically heated units. Illustrated. Write for Catalog ND 44 (3).

The Gaertner Scientific Corp., 1201 Wrightwood Ave., Chicago 11, Ill. Bulletin 143-74, "Gaertner Photoelasticity Polariscopes" describes apparatus used for obtaining experimental solutions to problems of stress distribution in mechanical parts and structures. The booklet includes optical diagrams and specifications covering three sizes of assemblies together with descriptions of various useful accessories. Eight pages; 8½ by 11 in. Illustrated.

Westinghouse Electric Corp. Sixteen types of mercury vapor lamps are described in a new 24-page booklet announced by the Lamp Division of Westinghouse. The booklet contains detailed information on electric discharge through vaporized mercury; technical data for the 16 types of vapor lamps available; spec-

tral radiation characteristics of vapor lamps at different arc pressures; auxiliary equipment available; operating characteristics of vapor lamps; lamp construction; lamp life and lument maintenance; effect of ambient and lamp temperatures on lamp life; and application information. Copies of the new booklet (A-5112) may be secured from the Advertising and Sales Promotion Department, Westinghouse Lamp Division, Bloomfield, N. J.

General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass. An eight-page folder entitled "New Variac Continuously Adjustable Transformers" describing the new "V" series. In the folder general specifications are given; type 200-B Variac is described, and also types V-5, V-10, and V-20, as well as type 50. Illustrated, 8½ by 11 in.

Thwing-Albert Instrument Co., Penn St. and Pulaski Ave., Philadelphia 44, Pa. A 16-page booklet, P-478, describing the Thwing-Albert Electro-Hydraulic Tensile Strength Tester. Among the material included is a brief historical background, breakdown of the instrument into component parts, diagrams and pictures, models and ranges available, operational details, accessory items, and a wealth of other information. Illustrated.

King Refrigeration Co., La Crescent, Minn. A four-page folder, "King Petroleum Laboratory Equipment," describes the cloud and pour point test cabinet and distillation apparatus for petroleum products. Illustrated.

Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Pa. "Laboratory Safety," a 36-page manual, is especially published for laboratories and presents various phases of accident prevention, first aid treatment, fire prevention and safety equipment. Specific dangers encountered in laboratory work are discussed under the headings: Storage Risks, Handling Risks, Faulty Techniques, Electrical Shock, Burns, Toxic Fumes, Poisons, Fires, Explosions and Disposal Risks. Copies of the booklet can also be obtained from Fisher Scientific Co. at 2109 Locust St., St. Louis 3, Mo., or from Eimer and Amend, 635 Greenwich St., New York 14, N. Y.

W. H. & L. D. Betz, Gillingham and Worth Sts., Philadelphia 24, Pa. An article entitled "Substitutes for Soda Ash in the Treatment of Boiler Feed Water" discusses various methods that may be employed to secure properly treated feedwater using little or no soda ash. A particularly useful and practical discussion in view of the soda ash shortage that has existed for some time. This article is designated as Betz Technical Paper No. 110, and will be furnished free upon request to W. H. & L. D. Betz.

Koehler Instrument Co., 168-56 Douglas Ave., Jamaica 3, N. Y. A four-page folder describing "The S.I.L. Mobilometer" with sections covering General Description, Scope, Reproducibility, Special Features, Applications, etc. This Mobilometer is a special type of falling weight viscometer. Illustrated.

Hofman Laboratories, Inc., 212 Wright St., Newark 5, N. J. A four-page folder entitled "Containers and Flasks for Liquefied Gases" describes products meeting present-day needs in nuclear physics and jet propulsion, as well as in many chemical processes involving the use of liquefied gases. Illustrated.

Instrument Notes:

K & K Engineering Co. Bolton N. Y., The Stroboflow—an Oscilloscope for Hydraulics for reproducing desired rates of flow in liquids comprises a precision-made turbine, mounted on stainless steel pivots in Graphitar bearings between transparent panes, and allowed to rotate, practically floating in synchronism with the liquid. The rotational speed of the turbine is used as a measure of the quantity of liquid flowing. Since there is a straight-line relationship between the speed of the rotor and the quantity of the liquid, and since the Stroboflow provides a very precise means of determining rotor speed, these two factors are combined in this instrument and constitute a highly accurate method of flow-rate indication. The rotor's speed is determined from the stroboscopic effect of light viewed through an aperture in the turbine disk. This instrument is of very simple construction. The use of it will simplify measurements of pump capacity, and will contribute to the simplification of many other hydraulic control problems, such as the measurement of fuel consumption in combustion processes.

Torsion Tester—No. D-2043—Semple Developments Co., 1324 N. Rockhill Road, St. Louis 17, Mo. It is designed for testing the low-temperature flexibility of plasticized materials.

Gilmont Ultra-Microburet—The Emil Greiner Co., 161 Sixth Ave., New York 17, N. Y. This instrument is designed to meet the most exacting requirements of scientists and technicians for an instrument capable of rapid titration with complete elimination of nerve-racking manipulation. In this new instrument a precision stainless steel plunger displaces mercury in a reservoir sealed off by a silicone rubber gasket contained in an aluminum bushing. The displaced mercury in turn forces a precisely determined amount of titrating solution through the fine orifice immersed in the solution being analyzed. Constructed entirely of corrosion-resistant materials, the Ultra-Microburet has a total displacement of 0.1 ML. with accuracy of 0.03 per cent of total displacement. Microburets for total displacements of 1 ML. (in 1/1000 ML.) or 0.01 ML. (in 1/100,000 ML.) are also available upon special order.

Mixaire—A New Type Of Air Motor Stirrer—The Emil Greiner Co. This achieves variable speed from 0 to 6000 rpm. and can replace electric motors in 0 to ½-hp. range. This device cannot explode under any conditions, does not generate sparks, and more than meets all safety requirements. Recommended for pressures below 100 lb. and speeds below 6000 rpm., the Mixaire's variable speed can be instantly increased or decreased by adjusting the valve on the air supply. It is of compact size, has simple speed control, automatic take-off, silent operation, and simplicity of design. Supplied with pulley and chuck for shafts up to ¼ in. diameter, nickel-plated stirrer, 9-in. shaft, and 2-in. diameter propeller.

Fibrograph—The Fulton Sylphon Division, Robertshaw-Fulton Controls Co., Knoxville, Tenn. This is a new electronic instrument which eliminates guesswork in determining length and uniformity of cotton fibers. It employs light-sensitive photo tubes for scanning samples of parallel cotton fibers, and simultaneously traces a length-frequency curve. The geometrical properties of the resulting curve, in contrast to the fallibility of human eyes and judgment, make it possible readily and quickly to determine various average length intervals, variance and coefficient of variation.

New Low-Temperature Platinum Resistance Thermometer—Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia 44, Pa. Based on a design by Dr. H. J. Hoge of National Bureau of Standards, this calorimetric thermometer is only about one-eighth the size of L&N's standard high-precision platinum thermometer although it uses the same temperature-sensitive element. The thermometer has a platinum protecting tube, about 48 mm. long and 5.6 mm. outside diameter, and can be readily mounted entirely inside a calorimeter by casting in low-melting alloy. It is helium filled, and therefore usable down to approximately the boiling point of helium, about 5 K. Four-wire current and potential leads are brought out through a glass seal. Nominal resistance at 0 C. is 25.5 ohms. The instrument can also be employed as a primary standard for resistance thermometry between −190 and +500 C., and can be supplied either with or without N.B.S. certificate for that range. When it is used with the type G-2 Mueller Bridge, temperature measurements can be made to an accuracy of ±0.01 C., in the calibrated range.

Type E Galvanometer—Leeds & Northrup Co. This galvanometer has its moving system, magnet, lamp, scale and lamp transformer in a single compact case. Sensitivity is ample for many potentiometer and bridge circuits which formerly required L&N galvanometers having separate reading devices. It also has an added low sensitivity which is a great help in initial stages of measurement. The instrument's scale has 50 1-mm. divisions on either side of zero. Deflection is linear within 1 per cent. Zero is adjusted by turning a knob on the front of the instrument. Sturdy metal case provides electrical shielding.

A New Clamp Holder For Accommodating Heavier Rods in Assembling Laboratory Apparatus—Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Pa. The Jumbo Holder accommodates rods, pipe, or tubular clamps up to ¾ in. diameter; it can be attached to table tops, shelves, or panels. Its unusual shape permits attaching the holder in complex assemblies where the thumbscrews of an ordinary clamp holder would not be accessible.

Desk-Size Harris-Mitchell Glassware Washer—Fisher Scientific Co. The washer consists of a lower portion shaped like a Florence flask in which an upper portion shaped like a funnel is inserted. A side tubulature with rubber bulb permits the user to force air into the lower portion, creating a pressure which forces the cleaning solution into the funnel portion where the glassware is held. A strong jet of chromic acid solution, for example, floods the beaker interior which then is flushed with tap water and distilled water before use.

A Recording Hygrometer—Fisher Scientific Co. This hygrometer records relative humidity changes on handy charts which can be filed for future reference and is accurate within ±3 per cent in the range of 15 per cent to 100 per cent. The new hygrometer incorporates a sensitive hygroscopic diaphragm connected with a counterbalanced pen which records the

changes on a chart. A recording pen, activated by a connecting arm from the diaphragm, moves across the face of the chart as it is revolved by a clock mechanism. It operates for 30 hours without rewinding.

GLASS CUTTER—Fisher Scientific Co. This new cutter made of Kennametal which has an extremely hard and enduring cutting edge is recommended in place of the ordinary triangular file because of its extreme hardness and the fact that it will retain its cutting edge for a lifetime. The cutter consists of a blade 3½ in. long mounted in a convenient hard wood handle.

CONTOUR PROJECTOR—Eastman Kodak Co., Rochester 4, N. Y. This projector embodies a number of optical principles never before incorpated in an instrument of this type. It answers the need for more rapid and accurate inspection of precision parts. One of the advantages of this projector lies in an optical unit which provides screen brightness approximately ten times greater than that of conventional comparators, eliminating the need for hoods or curtains when used in lighted rooms. In addition to the fundamental improvements incorporated in the contour projector, a number of accessories have been designed for use with it by Kodak engineers.

MASTER WORM SECTION—Eastman Kodak Co. A new concept of gear inspection based on the use of a gaging element produced as a single threaded worm has been announced by Eastman. This element can be manufactured with far greater accuracy than conventional master gears and can be used to check either spur or helical gears of the right or left hand regardless of helix angle. This master worm section provides a quick and economical means of checking composite error in gears.

An announcement has recently been made by the National Carbon Co. that the ATLAS ELECTRIC DEVICES Co., 361 W. Superior St., Chicago, Ill., has taken over the manufacture and sales of the National Weathering Unit Model XIA including repair parts, supplies, and service to present users. Atlas is well known in the field as the originator of weathering and fading equipment, and for over 25 years has manufactured the Weather-Ometer, Fade-Ometer and Launder-Ometer. Atlas is redesigning the Model XIA to incorporate the automatic cycling and other control features of the Atlas Twin-Arc Weather-Ometer but is retaining as a light source the well-known National Sunshine carbon arc. This redesigned weathering unit will be an addition to the regular Atlas line of Weather-Ometers, Fade-Ometers, and Launder-Ometers.

Tests of 77-Year-Old Wrought Iron

Submitted by C. W. Muhlenbruch[1]

A FOUR-masted schooner, the *Minnehaha*, was wrecked off Arcadia, Mich., in the storm of October 14, 1893, with a loss of six lives. This ship was built at Gibralter, Mich., in 1880, and its weight was 822 gross tons. It was valued at $25,000 and was carrying a cargo of 48,000 bushels of corn from Chicago, Ill., to Point Edward, Canada, when it was lost.

The wreckage of the hull, consisting principally of the main deck planking, and some of the ribs, has lain half submerged in the sand and water since the time of the wreck. The cyclic rise and fall of the level of Lake Michigan during the years has alternately exposed and submerged the remainder of the wreckage. During the winter of 1946–1947 parts of the wreckage were broken loose and washed into shore where they could readily be examined.

It was found that the deck spikes, and the pins used to fasten the heavier floor members together, were made of wrought iron and were in an excellent state of preservation, both inside and outside the wood. No other metallic parts were found in the wreckage so it is not known if other metals were used in the construction of the craft.

Because of the age of the wrought iron material and the exposure conditions to which it had been subjected it was considered of interest to test some of the parts in tension. The following table gives the dimensions of the spikes and the single pin which were tested, together with the results of the tests. No well-defined yield point was observed for any of the specimens It is interesting to note that even after 54 yrs. exposure all of the above specimens but one conform to A.S.T.M. Standard Specifications for Refined Iron Bars (A 41 – 36)[2] in so far as the tensile strength is concerned.

Specimen Form	Dimensions, in.	Tensile Strength, psi.	Elongation in 2 in., per cent
Spike.....	0.420 × 0.422	50 600	25.0
Spike.....	0.525 × 0.518	40 500	17.0
Spike.....	0.390 × 0.395	53 000	18.5
Pin.....	0.811 diameter	64 900	18.5

[1] Associate Professor of Civil Engineering, Carnegie Institute of Technology, Pittsburgh, Pa.

[2] 1946 Book of A.S.T.M. Standards, Part I-A, p. 548.

News of Instrument Companies and Laboratories

SPERRY PRODUCTS, INC., will move its manufacturing plant and general offices from Hoboken, N. J., to Danbury, Conn., during the summer of 1948. A twenty-acre site has been acquired and construction of a monitor-type manufacturing building and a three-story office building will begin immediately.

SAMUEL P. SADTLER & SON, INC., opened its enlarged laboratories at 2100 Arch St., Philadelphia 3, on February 16. The laboratories have been known for their general consulting, research, and referee analytical chemistry. The addition of new service such as organic, inorganic micro chemical laboratories, biochemical and bacteriological laboratories, and an absorption spectral laboratory for ultraviolet, visual, and infrared measurements, has necessitated this change.

Lectures on Statistical Methods

THE Massachusetts Institute of Technology has announced two series of lectures on statistical methods by L. H. C. Tippett, Chief Statistician, British Cotton Industry Research Association, with an address by Walter A. Shewhart, Bell Telephone Laboratories, the dates being early in May. The first five lectures by Mr. Tippett are from May 5–7, incl. the second series, May 12–14. The first group cover "Statistical Methods for Industrial Quality Control"; the second, the subject "Statistical Methods for Technical Investigation and Experimentation." Mr. Shewhart will speak at a dinner meeting on Friday, May 14, covering "The Future of Statistics in Industrial Research and Quality Control."

The fee for the lectures is $15 for each series; for the dinner meeting, $3. Checks should be made payable to D. L. Rhind, Bursar, M.I.T., but should be sent to Professor H. A. Freeman.

Symposium on Spectroscopic Equipment

THE Society for Applied Spectroscopy, in cooperation with the Polytechnic Institute of Brooklyn, announces a Symposium on Spectroscopic Equipment, to be held at the Polytechnic Institute of Brooklyn (85–99 Livingston St., Brooklyn 2, N. Y.) under the chairmanship of Dr. W. L. Parker, on Saturday, May 22, 1948. There will be a morning and an afternoon session. The meeting will start at 9:30 a.m. The latest developments on instruments in the field of absorption and emission spectroscopy will be exhibited by leading manufacturers.

Symposium on Cutting Oils

The work of a technical committee can be undertaken only after the problem has been defined and assessed. Technical Committee K on Cutting Oils was organized under Committee D-2 on Petroleum Products and Lubricants after a survey had been made among producers and consumers of cutting fluids, as well as technical men interested in evaluating cutting tools and cutting fluids, who predominately expressed the opinion that more information on the subject was needed.

These groups, therefore, have joined forces in Technical Committee K to study the characteristics of cutting fluids. The Symposium presented here, consisting of the following three papers, was held in Washington, D. C., January 18, 1947, in an attempt to assess the problems which confront the committee:

Water-Mixed Cutting Fluids, by William H. Oldacre.

Cutting Fluids, by E. A. Keehl.

Correlation of Laboratory Testing of Cutting Fluids with Field Tests, by D. J. Wangeli.

These papers have outlined some of the problems. Undoubtedly more will arise as the work progresses.

O. L. MAAG, *Chairman*

Water-Mixed Cutting Fluids

By William H. Oldacre[1]

ANY effort to organize the record of water-mixed cutting fluids, whether it be from the standpoint of history, usage, or function, is much confused from the beginning by inaccurate observations, careless terminology, and ambiguous reference.

It is not easy to determine just when water was first used as a lubricant in abrasive processes or in metal cutting, but it probably antedates accurately recorded history. With the introduction of ferrous metals in machines, the matter of rusting with the use of water became important, and in all probability it was found that the addition of a little alkali, soda ash, or sal soda helped to prevent rusting. When in the latter half of the nineteenth century machining speeds and feeds were increased, somebody discovered that the addition of lard oil to the soda water mixture produced a milky emulsion and increased machining efficiency. So little real thought and attention were given to the chemistry of this procedure that at one time a hot argument waged in one of the correspondence columns of a leading technical magazine[2] as to whether the mixture should be boiled or unboiled for best results. Boiling, of course, increased the percentage of soap formed, and thus tended to produce a soap solution rather than an emulsion of partially saponified fat.

Taylor's[3] comprehensive work, with his definite references to water as a cooling medium, introduced the "coolant." But there is little indication that Taylor, in spite of his care in dealing with other aspects of his problems, ever gave more than a passing thought to the water mixtures then possible and available.

A fairly diligent search reveals that soluble pastes became commercially available in the early 1900's, and there is substantial evidence to indicate that soluble oils were in use at least as early as 1912. However, in *American Machinist*, a correspondent[4] surmises that a commercial compound mentioned in the preceding volume was probably soluble creosote, and indicates that he found a soluble creosote, used for stock dip purposes, a satisfactory cutting fluid.

Since the first World War, emulsifiable products, either in the paste or oily form, have become commonplace. Today a wide variety of products is available, but there is little improvement in the understanding or care with which they are applied.

Generally speaking, all water-mixed cutting fluids are treated as water plus, and the plus is treated with the utmost indifference. Most of the water mixtures used during the past war years have been oil emulsions. As furnished commercially, they are in either an oily or paste form, and consist of mixtures of various soaps, oils, and solvents.

The complexities of their composition cannot be adequately treated in this paper, but it should be obvious that a wide variety of oils, both fatty and mineral, can be emulsified in varying degrees with a number of different types of soap.

Disregarding the intricacies of emulsion theory with reference to polarity, electrostatic charges, and surface tension, a cutting emulsion may be pictured with reasonable accuracy as minute droplets of oil covered with a protective film of water and soap, and suspended in a soap or soap and salt solution.

Generally speaking, the behavior of an emulsion is governed by its outer phase, and consequently cutting fluid emulsions do behave in some respects like soap solutions.

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[1] President, D. A., Stuart Oil Co., Ltd., Chicago, Ill.

[2] Ethan Viall referring to Louis Glaser, correspondents, *American Machinist*, Vol. 31, No. 1, pp. 622-914 (1908).

[3] F. W. Taylor, "On the Art of Cutting Metals," *Transactions*, Am. Soc. Mechanical Engrs., Vol. 28 (1906).

[4] A. C. H., correspondent, *American Machinist*, Vol. 33, Jan. 20, 1910, p. 11.

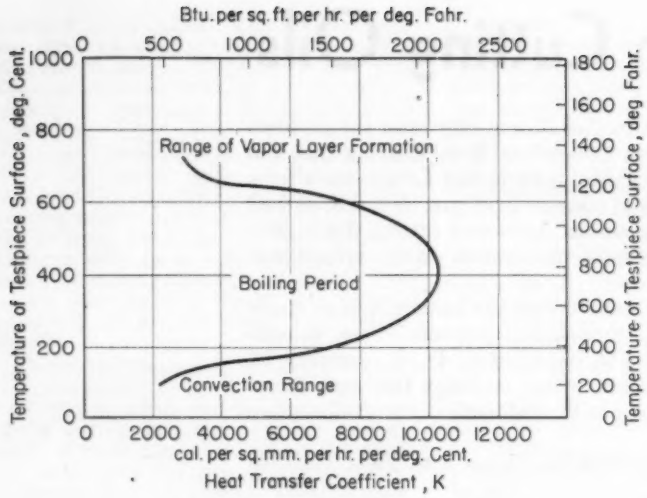

Fig. 1.—Heat Transfer Characteristics.

From W. Erlander, H. Avhend, and R. Wintrop. "Quenching Action in Relation to Cross Section," *Engineers Digest*, Vol. 3, No. 7, July, 1946.

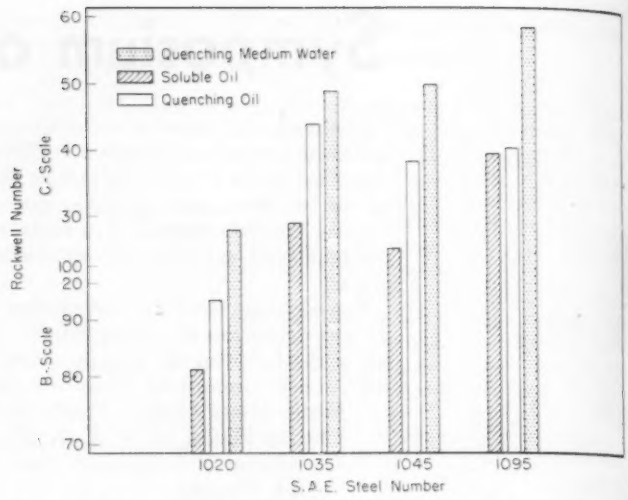

Fig. 2.—Results of a Quenching Test Made with Four Different Steels

Probably the rust-inhibiting and cooling characteristics of emulsions are in a large measure controlled by the concentration and types of soap in the outer phase. On the other hand, the lubricating characteristics are no doubt definitely affected by the nature of the oils in the suspended phase.

It is not unreasonable to assume that at the hot or heavily loaded points of contact between tool and work, when the water is driven off by heat, enough oil remains to perform a lubricating function.

Unfortunately the coolant idea has been so firmly entrenched in our thinking that it blinds us to important facts regarding the behavior of cutting fluids. Heat transfer characteristics of liquids are exceedingly complex, varying widely over temperature ranges involved in metal cutting (Fig. 1). Contamination also definitely changes heat-transfer characteristics. Thus, it has long been recognized that even a small amount of contamination from soaps or other organic material impairs the heat-transfer characteristics of water. In fact, a little soap in water will lower its quenching rate to below that of an ordinary oil. This fact has been ignored by cutting fluid and machinability technologists in their appraisals of cutting fluid behavior and their seemingly blind adherence to a coolant ideology.

Figure 2, from a paper presented at the recent meeting of The American Society of Mechanical Engineers,[5] gives the results of a quenching test made with four different steels and using oil, water, and soluble oil as the quenching media. As indicated by the hardness of the quenched pieces, the soluble mixture had the lowest cooling rate. Recognition of this fact compels revision of many popular cutting fluid concepts.

Complexities of metal-cutting processes and practice (*Allen*[6] claims 165,000,000 possible combinations based on the minimum number of variables) challenge us to give more care to theoretical formulation, better attention to practical performance, and more exact recording of results of both shop and laboratory tests.

Committee K of A.S.T.M. Committee D-2 is interested in tests with which to promote standardization. Tests are means of measurement and must be intimately related to function. It would seem, therefore, that any approach to a solution of our problems in water-mixed cutting fluids must wait on a careful and accurate survey of practice, and a comprehensive and intelligent study of the theory of metal cutting.

To a science which build Oak Ridge, and produced plutonium in quantity with little more than a suspicion of its existence as a guide, our problem should be a matter of comparatively simple organization. It is respectfully suggested that this committee could well content itself with an intelligent statement of this problem, and it is felt that such a statement would go a long way toward the solution.

[5] W. H. Oldacre and H. A. Erickson, "Some Observations on the Cooling Properties of Water-Mixed Cutting Fulids as Indicated by Quenching Tests," *Mechanical Engineering*, May, 1947, pp. 410–411.

[6] J. F. Allen, "Single Point Turning Research," *The Iron Age*, January 17, 1946, pp. 69–72.

Cutting Fluids[1]

By E. A. Reehl[2]

In the latter part of the nineteenth century, F. W. Taylor pioneered in the field of cutting fluids by proving that when water was directed on a cutting tool, the cutting speed could be increased approximately forty per cent. It can be safely said that this was the starting point for all cutting fluid research. Then, in turn, came the "soda-water" solutions, lard oil or lard oil - mineral oil mixtures, and so on down to the improved water solubles and sulfurized fatty and sulfurized mineral oils of today.

Cutting fluids have in the past been grouped in various ways, however. The following broad classification should suffice:

(*a*) Water-soluble cutting fluids.
(*b*) Non-water-soluble cutting fluids.

The water-soluble fluids are discussed in the paper by W. H. Oldacre.[3] The present paper is confined to the non-water-soluble type of cutting fluids, for which the following "breakdown" is proposed:

1. Straight mineral oils (100 sec. Saybolt at 100 F. oil): Always used in the as-received condition.
2. Sulfurized mineral oils (contains up to 2 per cent sulfur): Generally used in the as-received condition.
3. Sulfur-chlorinated mineral oils (contains approximately 3 per cent sulfur and about 1 per cent chlorine): Generally used in the as-received condition.
4. Sulfurized fatty oil (contains 5 to 15 per cent sulfur): Very seldom used straight; generally blended with 100 sec. Saybolt at 100 F. oil.
5. Sulfur-chlorinated oil (contains 5 to 15 per cent sulfur and approximately 1 to 2 per cent chlorine): Very seldom used straight; generally blended with 100 sec. Saybolt at 100 F. oil.

Straight Mineral Oils:

Mineral oils are suitable for light machining operations performed on steel, for cutting non-ferrous materials such as copper, bronze, and brass and for tapping and threading of white metals. Straight mineral oils are also recommended where lubrication and cooling characteristics are necessary but where these requirements are not severe. Such oils can also be used in place of water-soluble emulsions where the machine design will not permit the use of a water emulsion. For example, in applications such as automatic screw machines, trouble might result from water-soluble fluids replacing the lubricating oil in the bearings.

Sulfurized Mineral Oils:

Sulfur, when added correctly to mineral oil, increases its cooling and lubricating properties by preventing the welding of the metal chip to the tool face. This metallic film or iron sulfide formed between the chip and the tool, is produced by high temperatures generated by extremely high pressures created between the cutting tool and the work piece. The sulfurized mineral oils have been found particularly useful in the tapping, threading, and broaching operations and their ability to act as good, general-purpose cutting fluids for industry is well known. These oils, because of their ability to act as superior cutting fluids on the so-called "tough steels," that is, alloy steels, Monel metal, stainless steels, and the tough bronzes, have practically replaced all of the lard oil and lard oil - mineral oil mixtures of twenty years ago. If these highly sulfurized oils are used in the machining of non-ferrous metals such as copper, bronze, or brass, a discoloration due to formation of copper sulfide may occur; particularly is this true in damp, humid weather. This lone disadvantage is easily overshadowed by the many advantages shown in the use of sulfurized oils as a cutting and cooling medium.

Sulfur-Chlorinated Mineral Oils:

Chlorine can be added to mineral oils either alone or in combination with sulfur. Its function is not too well understood. One authority explains this function as one of acting as a "bridge" between the time that the mineral oil base ceases to function as a cutting fluid and that period in heat rise before the sulfur begins to act as an antiweld material. It is generally conceded today that chlorine, whether added to straight mineral oils or fatty oils, enhances the value of the cutting fluid.

Sulfurized Fatty or Vegetable Oils:

This type of oil was developed some thirty years ago. It had been known for years that the amount of sulfur that could be incorporated in a mineral oil was limited. Up to 2 per cent could be "cooked" into a mineral oil but a radical change in temperature or long storage in a drum or tanks would cause the sulfur to precipitate. Finally, after much work on the part of investigators, it was found that not only could sulfur be combined with fatty oils such as lard oil and sperm oil but in larger quantities than heretofore had been realized with mineral oils. Sulfur of the order of 10 to 15 per cent can be bonded with a fatty oil. These materials are often referred to as sulfurized base oils or fluids, primarily because before using they are usually blended with from five to twenty parts of a light-bodied mineral oil (100 sec. oil at 100 F. Saybolt viscosity). This makes a very handy tool for industry in that by being able to blend with this material, a wide variety of metal-cutting operations may be served.

Sulfur-Chlorinated Fatty or Vegetable Oils:

Chlorine, like sulfur, can be added to fatty oils as well as to mineral oils. As explained earlier, it imparts extreme pressure characteristics to cutting fluids. A combination of sulfur and chlorine incorporated in a fatty oil produces a light-colored, heavy-bodied base oil which can be used either in its

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[1] Presented at the meeting of Technical Committee "K" of Committee D-2 on Petroleum Products and Lubricants held January 18, 1947, at Washington, D. C.

[2] Works Laboratory, General Electric Co., Schenectady, N. Y.

[3] See page TP53.

unmodified form on difficult threading or broaching operations or "cut back" with a blending oil for a variety of machining operations.

It is of importance at this time to mention a few words concerning the worth of natural sulfur in mineral oils. Such oils may contain as much as 4 per cent naturally combined sulfur. However, tests by investigators of these materials have definitely proved that the sulfur in this state is of little value, if any, in metal cutting.

In closing, I should like to recommend for review an article called "How to Work with Cutting Fluids,"[4] published in *American Machinist* recently. The information for this article was obtained through such sources as the American Society for Metals, Carboloy Co., Cincinnati Milling Machine Co., Shell Oil Co., Socony-Vacuum Oil Corp., D. A. Stuart Oil Co., The Texas Company, and the University of Michigan, etc. It is quite complete and since it represents the combined efforts of leaders in the cutting fluid field, should be rated high on any reference list.

[4] Harold L. Flynn, "How to Work with Cutting Fluids," *American Machinist*, July 31, 1947.

Correlation of Laboratory Testing of Cutting Fluids With Field Tests

By D. J. Wangelin[1]

In discussing the testing of cutting fluids in the laboratory *versus* field testing, it is desirable to point out first what is meant by the term "field testing." Field testing as used in this discussion refers to closely controlled tests run in the cutting fluid user's plant under actual production conditions. This may be different from a field history on a given cutting fluid where experience over a relatively long time may indicate certain results.

It must be admitted that correlation between field testing and laboratory testing of cutting fluids has been something less than satisfactory. The blame for this discrepancy cannot be placed entirely on either of the test methods for both types of test have their weak points.

Field Testing:

Examining field testing, first we can cite the following advantages over a laboratory test. The conditions of the test are actual production conditions using the same machines, tools, and materials. There can be no complaint that the test conditions do not follow actual practice. The cost of such a test is much lower than laboratory testing, as the work done is productive work.

Many points must be considered, however, in getting good results from a field test. The management of the plant in which the test will be run must be willing to cooperate wholeheartedly in controlling all variables as closely as possible.

The machine tools used must be in good condition and free from chatter.

Cutting fluid sumps must be thoroughly cleaned each time a change is made in the cutting fluid.

The material cut must, of course, be uniform in analysis and structure for the entire test. If materials change from day to day there can be little hope of getting any reliable results from a cutting fluid test.

Tools must be of uniform quality and accurately ground to a predetermined shape. Tools should be ground in a fixture rather than ground by hand and the setting angles of the tools in the machine must be carefully controlled.

Speeds, feeds, and depth of cut must be unvaried for the duration of the test.

The quantity, velocity, and direction of the cutting fluid stream must remain constant as well as the temperature of the cutting fluid.

Some accurate means of determining tool failure must be used. This point usually is the main stumbling block in obtaining reliable results in a field test. It must be decided, initially, whether finish, dimensional accuracy, power requirements, or complete tool failure be used as the criterion to determine tool failure. The judgment of the machine operator is seldom reliable enough for accurate determination of tool failure.

Complete tool failure can seldom be reached in a production test unless the operation involves rough cuts only. Even in this case it is usually uneconomical to run tools to complete failure.

Few production machines are equipped with the necessary instruments to determine power input to the machine. Although it is relatively simple to attach a wattmeter to the machine, it will be difficult to determine changes in power requirements due to tool wear unless an extremely sensitive type of wattmeter is employed. Also if several tools are used in one machine it would be difficult to discover the offending tool from power measurements alone.

The most practical criteria to determine tool failure seem to be measurements of dimensional accuracy and changes in finish. Rigid inspection of the finished product will determine dimensional changes and the use of some type of surface analyzer will show changes in finish. Mere visual inspection of finish is usually not reliable unless the inspectors are exceptionally well trained in this type of work.

An important advantage of field testing over laboratory testing is the fact that the test is of sufficient duration and uses enough tools and material to cancel minor errors due to nonuniform material, tools, and tool failure times.

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[1] Plant Engineer, The Pure Oil Research and Development Laboratories, Winnetka, Ill.

Laboratory Test:

Laboratory tests can be divided into the following types:

1. Routine chemical analysis,
2. Mechanical tests to measure certain physical properties of a cutting fluid such as lubricity, anti-weld properties, cooling properties, wetting properties, wear properties, etc., and
3. Actual metal cutting tests.

The first type, chemical analysis, is used mainly in quality control and requires no discussion here.

The tests outlined in the second group can be valuable in the development of superior cutting fluids when used in conjunction with actual metal-cutting tests. Results of physical tests of this kind are helpful in explaining why a particular cutting fluid acts as it does in a metal-cutting test. The results of physical tests alone, however, may be quite misleading if they are not combined with the knowledge gained from metal-cutting tests.

Laboratory testing of cutting fluids in actual metal-cutting tests can be run on almost any type of machine tool. It is highly desirable, however, to use a relatively simple operation using a single point tool so that all variables inherent to the machine and its tooling can be kept to a minimum. A laboratory metal-cutting test differs from a field test principally in the test duration. In the laboratory we try to obtain cutting fluid performance data with a minimum of time and material. For this reason each variable must be more closely controlled because we cannot rely on a multiplicity of tests to smooth out differences due to imperfectly controlled variables.

Fortunately, in the laboratory these variables can be more closely controlled than in a field test. For instance, a complete series of tests can be run on one piece of material. If this piece is uniformly heat treated and free from inclusions, we can be fairly certain that the material variable is taken care of.

If a simple tool shape is used and adequate grinding fixtures are employed, tool shape may be accurately controlled. The importance of accurate tool grinding cannot be overemphasized in a short-time test of this kind.

Tools can be run to complete failure if desired. Frequently complete tool failure gives a more reproducible tool life than any other criterion. The shape of the cut is important in obtaining reproducible tool-life figures. For instance, in a simple turning operation with a single point tool, more reproducible tool-life figures usually can be obtained when the shape of the cut is such that the tool fails on the side cutting-edge rather than on the nose of the tool. Also, a fairly large nose radius is more stable than a small nose radius or a sharp-pointed tool.

The most important part of laboratory testing of cutting fluids is in the intelligent interpretation of results. It is necessary to have a knowledge of the mechanics of metal cutting and an understanding of the functions of a cutting fluid in different types of machining operations in order intelligently to apply the data obtained from laboratory tests to machining operations encountered in the field. The results obtained from *one* type of metal-cutting test cannot always be applied to *all* types of practical machining operations without considering the differences in the requirements of a cutting fluid in various types of machine tools.

Correlation Between Tests:

The failure to interpret test results intelligently is the primary reason for unsatisfactory correlation between laboratory tests and field tests. To enable us to use test data more intelligently we must get a clearer understanding of the mechanics of metal cutting and the action of a cutting fluid in various machining operations.

In turning operations, for instance, we know that a good cutting fluid increases tool life and produces a better finish on the work than that obtained in dry cutting. We know that tool temperature is reduced, cutting forces are reduced, and the size of the built-up edge on the tool is reduced. As yet, however, we do not know exactly how the cutting fluid performs these changes. Cooling, of course, is obvious, but just how a cutting fluid reduces tool forces and alters the shape of the built-up edge has not yet been demonstrated to everyones' satisfaction. Numerous theories have been expounded and no doubt many more will be presented in the future, but none as yet has been accepted by the industry.

The part that laboratory testing of cutting fluids can play is to give us more concrete knowledge of how a cutting fluid does its job so that some day we can speak of The *Science* of Cutting Fluid Application rather than The *Art* of Cutting Fluid Application.

A.S.T.M. Code Systems for Aluminum Alloys and Magnesium Alloys

By R. B. Smith[1]

Code systems are used by the Society for designation of light alloys, but the same system is not used for both aluminum alloys and magnesium alloys. The systems are similar, however. Each consists of one or more letters followed by one or more numbers. Examples: aluminum alloy CS41; magnesium alloy AS100.

Code Letters

In both code systems, letters identify "alloying elements." "Alloying elements" referred to here and below include only those specified in A.S.T.M. standards as a range or a minimum. When only a maximum percentage is specified for an element, that element is considered an impurity and is not included in the letter designation. The base metal is indicated with a letter only when it does not contain "alloying elements." In both code systems, the letters designating the "alloying elements" are arranged in order of decreasing amounts. The letters used are as follows:

A—Aluminum	M—Manganese
C—Copper	N—Nickel
D—Cadmium	R—Chromium
E—Cerium	S—Silicon
G—Magnesium	T—Tin
K—Zirconium	Z—Zinc

Magnesium Alloys:

In the magnesium alloy system, all "alloying elements" are identified in the code except small percentages of manganese which are present and essential in all of the alloys. So far, the number of letters in magnesium alloy designations has not exceeded two.

Aluminum Alloys:

Some aluminum alloys are, however, more complex and would require as many as five letters to identify them in the same manner. Since this would result in too long a designation, not more than two "alloying elements" are identified in aluminum alloy code designations.

Code Numbers

The greatest difference in the two code systems is the significance of the numbers which follow the code letters—in one they refer to *percentages* of "alloying elements"; in the other, they indicate the *number* of "alloying elements."

Magnesium Alloys:

For magnesium alloys, the numbers give the nominal percentage of each "alloying element" indicated in the designation by a letter. The numbers are arranged in the same order as the corresponding letters. When a range is specified for an element, the number shown as the nominal percentage is the mean of the range rounded off to the nearest whole number, using methods described in A.S.T.M. Tentative Recommended Practices for Designation of Numerical Requirements in Standards (E 29–40 T).[2] If only a minimum percentage for an element is specified, the minimum rounded off to the nearest whole number is considered as the nominal percentage. Magnesium alloys having the impurities iron and nickel controlled to low limits are indicated by the suffix *X*, which signifies high purity.

Aluminum Alloys:

For aluminum alloys, the numbers which follow the code letters indicate only the total number of "alloying elements," including those designated by the letters. Numbers below 20 indicate that not more than two "alloying elements" are present. Numbers between 20 and 40 signify three such elements, while numbers over 40 signify four or more. The alloys in any group (such as between CS20 and CS40) are numbered in sequence as they are accepted for inclusion in A.S.T.M. standards.

Examples[3]

Magnesium Alloys:

A.S.T.M. Tentative Specification B 107–47 T for Magnesium-Base Alloy Bars, Rods, and Shapes[4] covers four alloys, one of which requires the following chemical composition:

Element	Percentage
Aluminum	5.8 to 7.2
Manganese	0.15 min.
Zinc	0.4 to 1.5
Silicon	0.3 max.
Copper	0.05 max.
Nickel	0.005 max.
Iron	0.005 max.
Other impurities	0.3 max.
Magnesium	remainder

The elements aluminum and zinc are specified as a range, and thus are indicated by letters in the code designation. Although manganese is specified as a minimum percentage, it is not indicated in the code designation since small percentages of manganese are present and essential in all of the magnesium alloys.

The mean of the range specified for aluminum is 6.5 per cent; rounded off to the nearest whole number, this becomes 6 per cent for the nominal percentage. The mean of the range specified for zinc is 0.55 per cent; rounded off to the nearest whole number, this becomes 1 per cent for the nominal percentage.

Aluminum is indicated by the letter A, and zinc by the letter Z. Since the letters are arranged in order of decreasing amounts, the letter part of the code designation for this alloy is AZ.

The nominal percentage of aluminum for this alloy is 6 per cent, and the nominal for zinc is 1 per cent. Since the numbers are also arranged in order of decreasing amounts, the number part of the code designation is 61.

By combining the letters and the numbers, the code designation becomes AZ61. To this is added the suffix X to indicate that the impurities iron and nickel are controlled to low limits. Thus the alloy is designated as magnesium alloy AZ61X.

Aluminum Alloys:

A.S.T.M. Tentative Specification B 26–47 T for Aluminum Base Alloy Sand Castings[5] covers fifteen alloys, one of which requires the following chemical composition:

Element	Percentage
Copper	1.25 ± 0.25
Iron	0.8 max.
Silicon	5.0 ± 0.5
Manganese	0.5 max.
Magnesium	0.5 ± 0.1
Zinc	0.3 max.
Chromium	0.2 max.
Titanium	0.2 max.
Other elements	
Each	0.05 max.
Total	0.15 max.
Aluminum	remainder

The only elements considered in the code designation for this alloy are copper, silicon, and magnesium. They are the only ones specified as a range or a minimum.

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[1] Metallurgist, Reynolds Metal Co., Louisville, Ky.

[2] 1946 Book of A.S.T.M. Standards, Part 1A p. 1128.

[3] A.S.T.M. code designations and chemical composition limits for some aluminum alloys and magnesium alloys are listed in the companion article, "What's in an Alloy?" by John C. Kiska, Frankford Arsenal. See page (TP59) of this issue.

[4] 1947 Supplement to Book of A.S.T.M. Standards, Part I-B, p. 285.

[5] 1947 Supplement to A.S.T.M. Book of Standards, Part 1-B, p. 249.

Since not more than two "alloying elements" are indicated by letters in code designations for aluminum alloys only the silicon and copper, which have greater nominal percentages than the magnesium, are indicated by letters in the code designation for this alloy. Silicon is indicated by the letter S, and copper by the letter C. Since the letters are arranged in order of decreasing amounts, the letter part of the code designation for this alloy is SC.

The number part of the code designation is a number between 20 and 40 to indicate that the alloy contains three "alloying elements." This alloy was the first one assigned a number in this series, so it is designated as aluminum alloy SC21.

Proposed Code Systems

Within the past several years, a number of proposals to modify these code systems have been considered by A.S.T.M. Committee B-7, Subcommittee VII on Codification of Light Alloys. Although the various proposals did have merit, none was adopted since it was the consensus of the subcommittee that the modifications would not improve the codes enough to justify changing the established designations. However, the committee is of the opinion that much better code systems, or a single system for light alloys, could be developed, and any suggestions will receive every possible consideration.

What's in an Alloy?

By John C. Kiszka[1]

To answer the question "What's in an alloy?" requires more time than it should. In any attempt to recall the chemical composition of an alloy from the alloy designation, it immediately becomes evident that some alloy designations aid the memory in recalling chemical composition while many others do not. When it comes to indicating the chemical composition of an alloy, the A.S.T.M. designations of magnesium alloys are the best in the non-ferrous field. The designation of magnesium alloy AZ31 shows at once that it contains aluminum and zinc, and also gives the respective percentages in round numbers. For contrast with the magnesium alloy designations, consider the copper alloy designation, class 4A (Specifications B 145 – 46 T), or the designation, alloy No. XXIII, for a zinc-base alloy. These designations give no hint of what is in the alloy. The quiz that follows goes a little farther in illustrating the situation and at the same time affords an opportunity to test one's ability to recognize the alloys by their designations.

Most of the alloys in this quiz have two or more alloying elements for which maximum and minimum percentages are specified. Without consulting any further references, see how many of these alloys you know well enough to name the two major alloying elements and their respective percentages. Score one point for each element that you name correctly and one point for each percentage that you get right. For simplicity, give nominal percentages rounded off to the nearest whole number. The average score for this part of the test is estimated to be about 40. As the second part of the test, complete the information asked for in the quiz, consulting your usual references and record the time required for completion.

	A.S.T.M. Specification	Class or Grade	Element	Per cent	Element	Per cent
Aluminum-Base Alloys	B 211–47 T	CG21	——	—	——	—
	B 26–47 T	CG1	——	—	——	—
	B 26–47 T	CN21	——	—	——	—
	B 26–47 T	SC21	——	—	——	—
	B 26–47 T	ZG41	——	—	——	—
Magnesium-Base Alloys	B 80–47 T	A10	——	—	——	—
	B 80–47 T	A12	——	—	——	—
	B 91–45 T	TA54	——	—	——	—
	B 80–47 T	AZ63	——	—	——	—
	B 94–47 T	AZ91	——	—	——	—
Copper-Base Alloys	B 62–46	85–5–5–5	——	—	——	—
	B 61–46	....	——	—	——	—
	B 124–47	4	——	—	——	—
	B 30–45 T	6B	——	—	——	—
	B 124–47	3	——	—	——	—
Nickel-Base Alloys	B 83–46	....	——	—	——	—
	B 82–46	....	——	—	——	—
	B 164–41 T	A	——	—	——	—
	B 164–41 T	B	——	—	——	—
	B 39–22	X Shot	——	—	——	—
Zinc-Base Alloys	B 86–46	XXI	——	—	——	—
	B 86–46	XXIII	——	—	——	—
	B 86–46	XXV	——	—	——	—
Tin-Base Alloys	B 23–46 T	1	——	—	——	—
	B 23–46 T	2	——	—	——	—

Now consider what an alloy designation should contain. In general, an alloy consists of a base metal containing certain alloying elements (specified within controlled limits) and impurities. A system of designation which would indicate the major alloying elements and their respective percentages would enable completing the above quiz without reference to specifications. Such a system of designation should indicate two major alloying elements and should employ up to four digits to show the percentages. To keep the number of characters in the designation to a minimum, the alloying elements should be represented by single letters. The resulting designations would resemble the present A.S.T.M. magnesium alloy designations. Such a system, with modifications as described below, is applicable to all non-ferrous alloys.

Letter Symbols:

The symbols already in use in the A.S.T.M. magnesium and aluminum specifications are retained. Of the elements to be added, the most common ones are represented by a single letter as far as the alphabet permits.[2]

Further Classification:

If the present A.S.T.M. system for magnesium alloys were applied to all non-ferrous alloys, the practice of indicating all alloying elements contained in the alloy designation would result in designations which are too long and in some cases identical designations would be obtained for compositions differing only in impurity requirements. In the system proposed here, alloys which differ in details beyond 2 alloying elements and their percentages are distinguished by adding a letter to the designation. The final letter thus added indicates the complexity of the alloy by showing the number of alloying elements contained. These letters are assigned as shown in the Appendix.

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[1] Frankford Arsenal, Philadelphia, Pa.

[2] The element symbols are listed in the appendix of this paper.

TABLE I.—PROPOSED COMPOSITIONAL DESIGNATIONS FOR NON-FERROUS METALS.

ALUMINUM-BASE ALLOYS.

Proposed Code	A.S.T.M. Specifications	A.S.T.M. Class	Composition, per cent: Cu	Cr	Fe	Mg	Mn	Ni	Si	Ti	Zn	Others	Maximum Total Impurities
850A	B 37 - 46 T	IV	8.0	...	...	2.5	...	...	...	...	2.5	85.0 Al min.	15.0
920A	B 37 - 46 T	II	4.5	...	...	1.0	...	...	...	...	1.0	Al 92.0 min.	8.0
980A	B 37 - 46 T	Special	0.2	...	...	0.5	...	...	...	...	0.2	Al 98.0 min.	2.0
CG42F	B 211 - 47	CG21	3.8–4.9	0.25	0.50	1.2–1.8	0.3–0.9	...	0.50	...	0.10	Al rem.	0.15
CG42G	B 209 - 46 T	CG21	3.8–4.9	0.25	0.50	1.2–1.8	0.30–0.90	...	0.50	...	0.10	Al rem.	0.15
CG100A	B 26 - 47 T	CG1	9.2–10.8	...	1.5	0.15–0.35	0.5	0.3	2.0	0.2	0.5	Al rem.	0.3
CG100B	B 179 - 47 T	CG1	9.2–10.8	...	1.2	0.20–0.35	0.5	0.3	2.0	0.2	0.4	Al rem.	0.3
CM41R	B 211 - 47 T	CM41	3.5–4.5	0.25	1.0	0.2–0.8	0.4–1.0	...	1.0	...	0.10	Al rem. 0.3–0.7 Pb 0.3–0.7 Bi	0.15
S5A	B 26 - 47 T	S1	0.1	...	0.8	0.05	0.3	...	4.5–6.0	0.2	0.3	Al rem.	...
S5B	B 179 - 47 T	S1	0.1	...	0.6	0.05	0.3	...	4.5–6.0	0.2	0.3	Al rem.	...
S5C	B 26 - 47 T	S2	0.3	0.2	0.8	0.05	0.3	...	4.5–6.0	0.2	0.3	Al rem.	0.3
S5D	B 179 - 47 T	S2	0.3	0.2	0.6	0.05	0.3	...	4.5–6.0	0.2	0.3	Al rem.	0.3
S5E	B 179 - 47 T	S4	0.6	...	0.8	0.1	0.3	0.5	4.5–6.0	...	0.5	Al rem. 0.1 Sn	0.2
S5AA	B 85 - 46 T	S4	0.6	...	2.0	0.1	0.3	0.5	4.5–6.0	...	0.5	Al rem. 0.1 Sn	0.2
S5AB	B 184 - 43 T	A143	0.4	...	0.8	0.05	0.3	...	4.5–6.0	0.2	0.2	Al rem.	0.3

COPPER-BASE ALLOYS.

Proposed Code	A.S.T.M. Specifications	A.S.T.M. Class	Composition, per cent: Al	Fe	Mn	Ni	P	Pb	Sb	Si	Sn	Zn	Others	Maximum Total Impurities
6900A	B 14 - 18	...	...	0.10	...	...	...	0.50	...	...	...	rem.	69.00 Cu min.	0.50
840A	B 111 - 47	Red brass	...	0.06	...	...	...	0.075	...	...	...	rem.	84.0 Cu min.	...
9400A	B 105 - 47	...	3.50	0.75	0.75	...	...	...	...	3.00	5.00	...	94.00 Cu min. 1.50 Cd	0.50
9970A	B 72 - 47 T	...	...	0.010	...	0.100	...	0.010	0.012	...	...	...	99.70 Cu + Ag min. 0.100 As, 0.003 Bi, 0.075 O, 0.040 Se 0.050 Sn, 0.014 Te	...
9988A	B 216 - 47 T	...	...	...	...	0.05	...	0.004	0.003	...	...	...	99.88 Cu + Ag min. 0.012 As, 0.025 Se + Te 0.003 Bi	...
9990A	B 12 - 47	b	...	...	...	...	...	...	...	...	...	...	99.90 Cu + Ag min.	...
9990B	B 111 - 47	copper	...	...	...	...	0.035	...	...	...	...	...	99.90 Cu + Ag min.	...
AN105F	B 150 - 46 aT	II	9.00–11.00	2.00–4.00	1.50	4.00–5.50	...	...	...	0.25	0.20	...	78.00–85.00 Cu	0.50
AN106L	B 171 - 47	...	8.00–11.00	1.50–3.50	0.50–2.00	4.00–7.00	...	...	...	...	...	...	Cu rem.	0.50
AN114F	B 30 - 45 T	9D	10.0–11.5	3.0–5.0	3.5	3.0–5.5	...	...	...	...	...	...	78.0 Cu Min.	0.50
J0A	B 11 - 47	gr2	...	...	...	...	0.015–0.040	...	...	...	...	...	99.90 Cu + Ag min.	...
J0B	B 68 - 47	A	...	...	...	...	0.004–0.012	...	...	...	...	...	99.90 Cu + Ag min.	...
J10A	B 52 - 46	B	...	0.15	...	...	10.0 min.	...	...	...	...	...	99.75 P + Cu min.	...
N31B	B 111 - 47	70-30CuNi	...	0.6	1.0	29.0–33.0[a]		0.05	...	...	1.50	1.0	Cu + Ag rem.	...
NZ214B	B 122 - 47 T	7	...	0.60	1.00	19.0–23.0[a]	...	0.05	...	...	1.00	3.00–6.00	Cu rem.	...
PT55F	B 62 - 46	85-5-5-5	...	0.30	...	1.0	0.05	4.0–6.0	...	...	4.0–6.0	4.0–6.0	84.0–86.0 Cu	...
TP51F	B 103 - 47	B1	...	0.10	...	...	0.03–0.35	0.80–1.25	...	...	3.50–5.80	0.30	Cu rem.	...
ZP371A	B 132 - 46 T	A	1.50	2.00	1.50	...	...	0.50–1.50	...	...	1.50	rem.	56.0–62.0 Cu	...
ZP371B	B 147 - 46 T	7A	1.5	2.0	1.5	...	...	0.5–1.5	...	...	1.5	rem.	56.0–62.0 Cu	...

[a] Cobalt counting as nickel.

LEAD-BASE ALLOYS

Proposed Code	A.S.T.M. Specifications	A.S.T.M. Class	Composition, per cent: Ag	Al	As	Bi	Cu	Fe	Sb	Sn	Zn	Others
9973A	B 29 - 43	CDLB[a]	0.002	...	As + Sb + Sn 0.015	0.15	0.0025	0.002	...	...	0.002	99.73 Pb min.
9994A	B 29 - 43	CRL[a]	0.0015	...	0.0015	0.05	0.0015	0.002	Sb + Sn 0.0095	...	0.0015	99.94 Pb min.
C0A	B 29 - 43	AL[a]	0.002	...	As + Sb + Sn 0.002	0.025	0.040–0.080	0.002	...	...	0.001	99.90 Pb min.
C0B	B 29 - 43	CL[a]	0.020	...	As + Sb + Sn 0.015	0.010	0.040–0.080	0.002	...	...	0.002	99.85 Pb min.
CQ00A	B 29 - 43	CHL[a]	0.002–0.20	...	As + Sb + Sn 0.002	0.005	0.040–0.080	0.002	...	...	0.001	99.90 Pb min.
Q3A	B 32 - 46 T	01	2.3-2.7	0.005	...	0.25	0.3	0.02	0.40	0.25	0.005	97.5 Pb
QT21A	B 32 - 46 T	02	1.3-1.7	0.005	...	0.25	0.3	0.02	0.040	0.75–1.25	0.005	97.5 Pb
T2A	B 32 - 46 T	2B	...	0.005	...	0.25	0.08	0.02	0.50	1.5–2.5	0.005	98 Pb
T5A	B 32 - 46 T	5B	...	0.005	...	0.25	0.08	0.02	0.50	4.5–5.5	0.005	95 Pb
T10A	B 32 - 46 T	10B	...	0.005	...	0.25	0.08	0.02	0.50	10	0.005	90 Pb
T15A	B 32 - 46 T	15B	...	0.005	...	0.25	0.08	0.02	0.50	15	0.005	85 Pb
T40A	B 32 - 46 T	40A	...	0.005	...	0.25	0.08	0.02	0.12	40	0.005	60 Pb
T40B	B 32 - 46 T	40B	...	0.005	...	0.25	0.08	0.02	0.50	40	0.005	60 Pb

[a] CRL, Corroding lead; CHL, chemical lead; AL, acid lead; CL, copper lead; CDLA, common desilverized lead A; CDLB, common desilverized lead B; SUL, soft undesilverized lead.

TABLE I. (Continued)

MAGNESIUM-BASE ALLOYS.

Proposed Code	A.S.T.M. Specifications	A.S.T.M. Class	Composition, per cent: Al	Ca	Cu	Fe	Mn	Ni	Si	Sn	Zn	Others	Maximum Total Impurities
AM80A	B 80 – 47 T	A8	7.8–9.2	...	0.10	...	0.15 min.	0.01	0.3	...	0.3	Mg rem.	0.3
AM80B	B 93 – 47 T	A8	8.0–9.0	...	0.08	...	0.18 min.	0.01	0.2	...	0.20	Mg rem.	0.3
AM100A	B 80 – 47 T	A10	9.0–11.0	...	0.10	...	0.10 min.	0.01	0.3	...	0.3	Mg rem.	0.3
AM100B	B 199 – 47 T	A10	9.3–10.7	...	0.10	...	0.10 min.	0.01	0.3	...	0.3	Mg rem.	0.3
AM100C	B 199 – 47 T	A10X	9.3–10.7	...	0.05	0.005	0.10 min.	0.005	0.3	...	0.3	Mg rem.	0.3
AM100D	B 93 – 47 T	A10	9.4–10.6	...	0.08	...	0.13 min.	0.01	0.2	...	...	Mg rem.	0.3
AM100E	B 94 – 47 T	AS100	9.0–11.0	...	0.05	...	0.10 min.	0.03	1.0	...	0.3	Mg rem.	0.3
AM100AA	B 93 – 47 T	AS100	9.4–10.6	...	0.08	...	0.13 min.	0.01	1.0	...	...	Mg rem.	0.3
AM120A	B 80 – 47 T	A12	11.2–12.8	...	0.10	...	0.10 min.	0.01	0.3	...	0.3	Mg rem.	0.3
AM120B	B 93 – 47 T	A12	11.5–12.5	...	0.08	...	0.13 min.	0.01	0.2	...	...	Mg rem.	0.3
AZ31F	B 107 – 47 T	AZ31X	2.5–3.5	...	0.05	0.005	0.20 min.	0.005	0.3	...	0.6–1.4	Mg rem.	0.3
AZ31G	B 91 – 45 T	AZ31X	2.5–3.5	...	0.05	0.005	0.20 min.	0.005	0.3	...	0.7–1.3	Mg rem.	0.3
AZ31H	B 90 – 46 T	AZ31X	2.5–3.5	0.3	0.05	0.005	0.20 min.	0.005	0.3	...	0.6–1.4	Mg rem.	0.3
AZ51F	B 90 – 46 T	AZ51X	4.1–5.5	0.3	0.05	0.005	0.15 min.	0.005	0.3	...	0.4–1.3	Mg rem.	0.3
AZ63F	B 80 – 47 T	AZ63	5.3–6.7	...	0.25	...	0.15 min.	0.01	0.3	...	2.5–3.5	Mg rem.	0.3
AZ80F	B 107 – 47 T	AZ80X	7.8–9.2	...	0.05	0.005	0.12 min.	0.005	0.3	...	0.2–0.8	Mg rem.	0.3
AZ92F	B 80 – 47 T	AZ92	8.3–9.7	...	0.25	...	0.10 min.	0.01	0.3	...	1.6–2.4	Mg rem.	0.3
AZ92G	B 199 – 47 T	AZ92	8.3–9.7	...	0.25	...	0.10 min.	0.01	0.3	...	1.7–2.3	Mg rem.	0.3
AZ92H	B 93 – 47 T	AZ92	8.5–9.5	...	0.20	...	0.13 min.	0.01	0.2	...	1.7–2.3	Mg rem.	0.3
AZ101F	B 80 – 47 T	AZ101	9.0–11.0	...	0.10	...	0.10 min.	0.01	0.3	...	0.5–1.5	Mg rem.	0.3

NICKEL-BASE ALLOYS.

Proposed Code	A.S.T.M. Specifications	A.S.T.M. Class	Composition, per cent: Al	C	Cr	Cu	Fe	Mn	S	Si	Others
9900A	B 160 – 41 T	...	...	0.20	...	0.25	0.50	0.35	0.02	0.50	99.00 Ni min.
9900B	B 175 – 45 T	...	...	0.20	...	0.20	0.30	0.35	0.008	0.20	99.00 Ni min.
9775A	B 39 – 22	A-Shot	...	0.75	...	...	0.90	...	0.070	...	97.75 Ni min.
9850A	B 39 – 22	...	...	...	...	...	...	...	...	...	98.50 Ni min.
9890A	B 39 – 22	X-Shot	...	0.25	...	...	0.60	...	0.05	...	98.90 Ni min.

SILVER-BASE ALLOYS.

Proposed Code	A.S.T.M. Specifications	A.S.T.M. Class	Composition, per cent: Cu	Zn	Others	Maximum Total Impurities
CZ164A	B 73 – 29	8	15–17	2–6	79–81 Ag	0.15
CZ2010A	B 73 – 29	7	19–21	8–12	69–71 Ag	0.15
CZ2015A	B 73 – 29	6	19–21	13–17	64–66 Ag	0.15
CZ3025A	B 73 – 29	4	29–31	23–27	44–46 Ag	0.15
CZ3416A	B 73 – 29	5	33–35	14–18	49–51 Ag	0.15

TIN-BASE ALLOYS.

Proposed Code	A.S.T.M. Specifications	A.S.T.M. Class	Composition, per cent: Al	As	Bi	Cu	Fe	Pb	Sb	Zn	Others
CY44A	B 102 – 44	1	0.01[a]	0.08	...	4–5	0.08	0.35	4–5	0.01	90–92 Sn
CY44B	B 23 – 46 T	1	0.005	0.10	0.08	4.0–5.0	0.08	0.35	4.0–5.0	0.005	90.0–92.0 Sn
CY88A	B 23 – 46 T	3	0.005	0.10	0.08	7.5–9.0	0.08	0.35	7.5–9.0	0.005	82.5–84.5 Sn
P30A	B 32 – 46 T	70A	...	...	...	...	...	30	0.12	...	70 Sn
P30B	B 32 – 46 T	70B	...	...	...	...	...	30	0.50	...	70 Sn

ZINC-BASE ALLOYS.

Proposed Code	A.S.T.M. Specifications	A.S.T.M. Class	Composition, per cent: Al	Cd	Cu	Fe	Mg	Pb	Sn	Zn	Others
9832A	B 6 – 46	5	...	...	...	0.08	...	1.60	...	...	...
990A	B 6 – 46	3	...	0.50	...	0.03	...	0.60	...	...	1.0 Pb + Fe + Cd
9950A	B 6 – 46	2	...	0.50	...	0.03	...	0.20	...	...	0.50 Pb + Fe + Cd
9990A	B 6 – 46	1	...	0.07	...	0.02	...	0.07	...	...	0.10 Pb + Fe + Cd
99990A	B 6 – 46	1a	...	0.004	...	0.005	...	0.006	...	...	0.010 Pb + Fe + Cd
AC41F	B 86 – 46	XXV	3.5–4.3	0.005	0.75–1.25	0.100	0.03–0.08	0.007	0.005	rem.	...
AC43F	B 86 – 46	XXI	3.5–4.5	0.005	2.5–3.5	0.100	0.02–0.10	0.007	0.005	rem.	...
AG40A	B 86 – 46	XXIII	3.5–4.3	0.005	0.10	0.100	0.03–0.08	0.007	0.005	rem.	...

Base Metal:

If an alloy designation is quoted in a reference where the base metal being referred to is obvious from the context (as is most often the case), mention of the base metal with the designation is not required. When the base metal is not obvious, the designation is preceded by the full name of the base metal.

Unalloyed Metals:

The unalloyed metal is indicated by the name of the metal followed by the specified minimum purity, all digits retained but dropping the decimal point. A final letter is added to differentiate metals of similar requirements for the base metal but having different impurity requirements.

This expanded system provides distinct designations for all non-ferrous metals and alloys. The quiz given above proved to be difficult because most of the present designations do not show what is in the alloy. Having described a system of designation which does show what is in the alloy, let us see how the quiz looks with these new designations.

	A.S.T.M. Specification	Class or Grade	Proposed Designation
Aluminum-Base Alloys	B 211–47 T	CG21	CG42F
	B 26–47 T	CG1	CG100A
	B 26–47 T	CN21	CN42F
	B 26–47 T	SC21	SC51F
	B 26–47 T	ZG41	ZG61L
Magnesium-Base Alloys	B 80–47 T	A10	AM100A
	B 80–47 T	A12	AM120A
	B 91–45 T	TA54	TA54F
	B 80–47 T	AZ63	AZ63F
	B 94–47 T	AZ91	AZ91F
Copper-base Alloys	B 62–46	85–5–5–5	PT55F
	B 61–46	....	TZ64F
	B 124–47	4	ZF391F
	B 30–45 T	6B	ZP292A
	B 124–47	3	ZT391A
Nickel-Base Alloys	B 83–46	.....	RS161A
	B 82–46	.....	RS201A
	B 164–41 T	A	C31A
	B 164–41 T	B	CW310A
	B 39–22	X Shot	9890A
Zinc-Base Alloys	B 86–46	XXI	AC43F
	B 86–46	XXIII	AG40A
	B 86–46	XXV	AC41F
Tin-Base Alloys	B 23–46 T	1	CY44B
	B 23–46 T	2	YC84A

The elements represented in the quiz are:

Aluminum	A	Iron	F	Silicon	S
Antimony	Y	Lead	P	Sulfur	W
Copper	C	Manganese	M	Tin	T
Chromium	R	Magnesium	G	Zinc	Z

The element symbols were assigned so that they might be memorized easily by association with chemical symbols or the spelling of the names of the elements. The amount of memory work required in the use of this system is determined by the scope of the user's interest, just as we retain in our memory only those chemicals symbols that concern our interests. To one who is interested in the entire non-ferrous field, this system may appear complex, but in comparison with the various nondescriptive systems of designation used in present specifications, the proposed system presents a great simplification. The proposed system has been applied to all compositions given in the A.S.T.M Standards, Part IB-Non-Ferrous Metals, and a unique designation is obtained for each composition. Some typical examples of the designations obtained in the proposed code are shown in Table I.[3] The Government agencies and A.S.T.M. cooperate on many matters of specifications. Both should be interested in speaking the same "language" in their specifications. The quiz given above illustrates the time required in arriving at recognition of an alloy composition with present designations. The designations in Government specifications present the same difficulties. By adopting the proposed system, both would be using designations which can be quicky interpreted.

APPENDIX
RULES GOVERNING DESIGNATIONS

Alloys:

Alloy designations consist of one or two element symbols, one to four digits showing respective percentages, and a final letter.

Elements Represented:

At most two alloying elements are represented by their assigned symbols in order of the amount present, with the symbol for the element present in greatest amount first, or in alphabetical order if present in equal amounts.

[3] Table I in its entirety is on file at the A.S.T.M. Headquarters.

Note.—An alloying element is defined as an element contained in the base metal within a specified range or in excess of a specified minimum percentage. The amount present is determined by the mean of the range (or minimum percentage) before rounding off.

The element symbols are as follows:

A	Aluminum	J	Phosphorus	R	Chromium
B	Bismuth	L	Beryllium	S	Silicon
C	Copper	M	Manganese	T	Tin
D	Cadmium	N	Nickel	V	Arsenic
F	Iron	P	Lead	W	Sulfur
G	Magnesium	Q	Silver	Y	Antimony
				Z	Zinc

Respective percentages in whole numbers follow the alloying element symbols in the designation.

In rounding off percentages, the procedure described in A.S.T.M. Standard E 29–40 T[4] is used.

When a range is specified for the alloying element, the rounded off mean is used in the designation.

When only a minimum percentage is specified for the alloying element, the rounded off minimum percentage is used in the designation.

When an alloying element is specified as the remainder, the percentage used in the designation is found by computing the possible range in accordance with the percentages specified for the other elements and rounding off the mean of the range. Elements specified as the remainder are ignored in the designation when only a minimum percentage is specified for the base metal.

Final Letter:

The final letter indicates the total number of alloying elements specified for the alloy as shown in the following table:

Final Letter	No. of Alloying Elements	Spare Letters
A	1 or 2	B C D E
F	3	G H J K
L	4	M N P Q
R	5	S T U V
W	6	X Y
Z followed by a number	7 or more	

The spare letters are applied in turn to distinguish alloy compositions which otherwise would result in identical designations.

Base Metal:

The full name of the base metal precedes the alloy designation, but it is omitted for brevity when the base metal being referred to is obvious.

Unalloyed Metals:

Unalloyed metal is indicated by the specified minimum purity, all digits retained but dropping the decimal point. A final letter is added to differentiate metals of similar requirements for the base metal but having different impurity requirements.

[4] Tentative Recommended Practices for Designation of Numerical Requirements in Standards, 1946 Book of A.S.T.M. Standards, Part 1-A, p. 1128.

An Instrument for Determining the Volume and Bulk Density of Granular Materials

By William E. Gross[1] and John C. Goshorn[1]

EDITOR'S NOTE—While the apparatus described in this paper was designed for a somewhat limited use, it is published here with the thought that it could be applied to the testing of other materials such as, possibly, fine aggregate for concrete.

SYNOPSIS

The two instruments that are described in this paper are of simple and inexpensive design. They have proved to be entirely satisfactory for measuring the volume of gas mask canister adsorbents and other granular materials used in these canisters and other containers and for measuring out specific quantities of charcoal or other granular materials for filling into gas mask canisters and other containers; for determining the bulk density of various granular materials; and for determining the percentage of voids between granules in packed materials.

The two instruments are similar in principle but are of different mechanical design and capacity. Either mechanical design may be used, however, as the results obtained on both are identical. The instruments are fully protected by letters patent.[2] Their development is more completely described.[3]

It is believed that these instruments would be of considerable value to any industry where there is a need for a simple device to quickly determine and check the volume, bulk density, and percentage of voids in packed granular materials such as meals, cereals, soil, sand, gravel, gas mask canister charcoal, medicines in tablet and capsule form, coal, adsorbents such as silica gel, granular chemicals, and spherical materials such as lead shot and gunpowder. When used for gunpowder, the meter must be constructed of nonsparking materials, and the proper safety precautions (applicable to the explosive being measured) must be observed. These instruments can also be used to great advantage in checking the performance of vibrating machines used to pack foods and other materials in packaging containers, and as an inspection means to control the degree of packing in these containers. The instruments can be constructed of common materials, such as brass tubing, hardware cloth (wire screen), and graduated glass cylinders of 250 and 1000-ml. size. Standard machine and sheet metal tools can be used to fabricate them.

IN FILLING gas mask canisters it is important that the density of packing of the gas adsorbent be consistently maintained above a certain minimum value. Otherwise, the canister performance will be poor. The instruments described in this article were designed in connection with development and study of gas mask canisters in order to provide a very accurate means of determining the following: the degree of packing obtained in the canisters, determination of adsorbent volume, the percentage of void space existing between granules in canisters filled with material of a given mesh distribution, and the bulk density to volume ratio of the adsorbent for quality control in manufacture and for procurement purposes. (NOTE.—Gas mask canister adsorbent is purchased on a weight basis and filled into canisters on a volume basis.) The meters pack the adsorbent to practically the same density as is accomplished by the machines used to fill canisters. As a result of this correlation, calculation of the amount of adsorbent needed to fill a specific number of canisters, or determination of the void space existing between granules in filled canisters, is a simple operation.

No standard test method for determining the volume of packed granular material is known to exist.

A standard test method for determining bulk density (unit weight) of granular materials is available.[4] This test method, however, is not applicable for use with a soft material such as gas mask charcoal because the tamping rod crushes some of the granules. The test method also requires considerable time for its execution, and a reasonable amount of skill on the part of the operator.

A standard test method is available for determining the percentage of voids existing between granules in packed granular materials.[5] This particular test method involves considerably more work than the test method described in this paper. Also, a possibility exists that the standard test method may not be as accurate as the test method described herein. However, no work has been done to determine this.

The first method used by the Chemical Corps to determine volume consisted of pouring the granular material through a funnel directly into a graduated glass cylinder of suitable size and reading the volume directly in milliliters from the graduated cylinder. The second method to determine volume, used prior to the development of the volume meters, consisted of pouring the granular material into a graduated glass cylinder and tapping the base of the graduate against a solid surface, such as a lead block, for several minutes to settle the granular material therein. The volume was then read directly in milliliters from the graduated glass cylinder.

Prior to development of the volume meters, bulk density was determined by the Chemical Corps by pouring the adsorbent very slowly into a glass tube of approximately 1.4-cm. inside diameter. The tube was filled to a depth of 10 cm., and the bulk density was calculated by dividing the weight of adsorbent by the volume.

No test method for determining the percentage of voids in packed granular materials was used by the Chemical Corps prior to development of the volume meters.

DESCRIPTION AND OPERATION OF APPARATUS DEVELOPED

The E2R3 meter consists essentially of a base on which is mounted a tubular frame that contains a standard 1-liter graduated glass cylinder which has been modified by cutting off the top and bottom ends, a slide valve for closing the open bottom end of the graduated glass cylinder, a cylindrically shaped dis-

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] Chemical Corps Technical Command, Army Chemical Center, Maryland.

[2] J. C. Goshorn and William E. Gross, "Volume Meter for Granular Materials," U. S. Patent No. 2,332,512, October 26, 1943.

[3] William E. Gross and J. C. Goshorn, "Development of Volume Meters E2R3 and E4 for Determining the Volume and Apparent Density of Granular Materials," Technical Division Memorandum Report No. 1185, War Dept., Chemical Corps, Edgewood Arsenal, Md. (1946). This report is now listed as Publications Board Report No. 7230 and may be obtained from: Office of Publications Board, Dept. of Commerce, Washington 25, D. C.

[4] Standard Method of Test for Unit Weight of Aggregate (C 29–42), 1946 Book of A.S.T.M. Standards, Part II, p. 474.

[5] Standard Method of Test for Voids in Aggregate for Concrete (C 30–37), 1946 Book of A.S.T.M. Standards, Part II, p. 476.

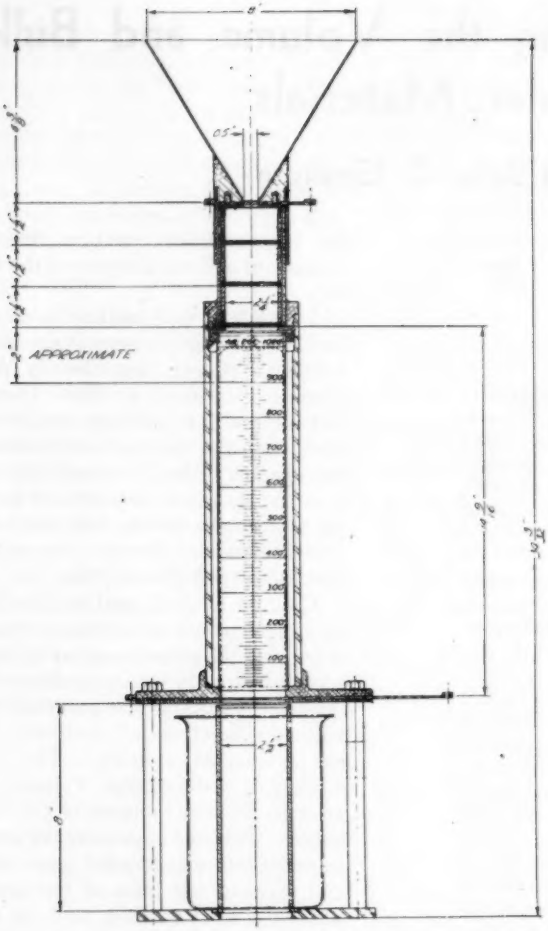

Fig. 1.—Schematic Diagram of Volume Meter E2R3 Used for Measuring Samples from 100 to 900 ml.

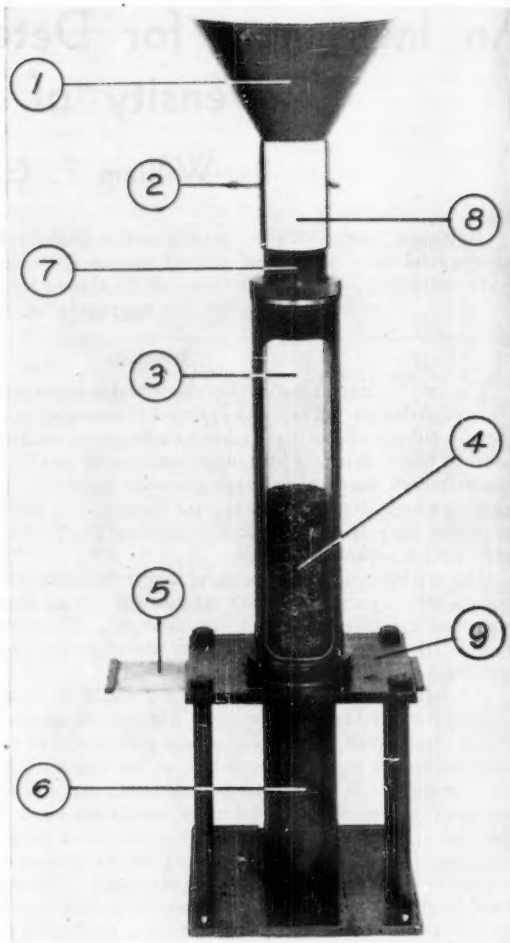

Fig. 2.—Volume Meter E2R3 Used for Measuring Samples from 100 to 900 ml.

persal head, a funnel-shaped hopper having a 0.5-in. diameter opening or orifice, a valve for closing the orifice, and a waste tube for conducting the discharged samples through a hole in the mounting table into a waste receptacle below. This meter is shown in Figs. 1 and 2. In Fig. 2 the following items are shown:

1. Sample hopper. This hopper has a 0.5-in. diameter hole in the bottom.

2. Slide type shutoff valve for controlling flow of material from hopper *1*.

3. Standard type 1-liter graduated glass cylinder that has been modified by cutting off the top and bottom ends. It is approximately 2.312 in. in inside diameter. A measured sample of granular material is seen in the lower portion of the cylinder.

4. Sample of granular material (gas mask canister adsorbent) in graduated cylinder.

5. Slide valve for closing bottom of graduated cylinder. This valve is closed except when discharging measured samples.

6. Discharge tube through which the samples are dropped, after measuring, through a hole in the top of the mounting table and into a receptacle below. This tube is mounted on a track and can be pushed back out of the way if desired. A suitable receptacle may be placed directly below the opening in slide valve *5* for collecting the sample.

7. Dispersal head for scattering the adsorbent, and distributing it evenly over the cross-sectional area of the graduate. This head contains three screens of 3-mesh hardware cloth. The screens are spaced 1.5 in. apart, with the uppermost screen located 1.5 in. below the orifice in the bottom of sample hopper *1*.

8. Calibration chart. All new graduates must be calibrated for volume. However, graduates of good quality are usually correct. If an error does exist, it is seldom more than 1 to 2 ml. and then only at certain points.

9. Supporting frame.

Volume meter E4 is the same in principle as the E2R3 but it is of smaller size and is of simpler and less expensive construction. Because of clogging due to the small diameter of the graduate and drop tube in this meter, it was necessary to employ a steel ball in the dispersal head for spreading the falling material instead of wire screen as used in the E2R3 meter. A smaller instrument than the E4 meter, which was designated volume meter E3, was also constructed. It was identical with volume meter E4 except that the diameter of the graduated cylinder and drop tube was smaller. Meter E3 was abandoned because it gave higher readings than both the E2R3 and the E4 meters, due to the small diameter of the graduated measuring cylinder (this factor is discussed later).

The E4 meter has a capacity of 250 ml., and the results obtained with it correlate well with those obtained on the E2R3 meter. The E4 meter is shown in Fig. 3, to which the following description applies:

1. Sample hopper. This hopper has a 0.5-in. diameter orifice in the bottom.

2. Upper support bracket for volume meter.

3. Drop tube (1.437-in. inside diameter). This tube has a 0.25-in. diameter steel ball located in vertical alignment with the orifice in the bottom of the sample hooper *1*. The ball is supported 1.5 in. below the orifice by a horizontal wire which passes through it

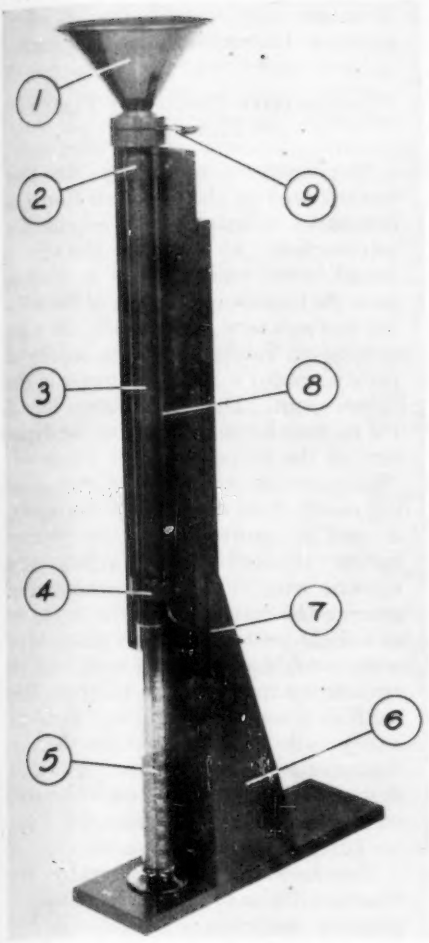

Fig. 3.—Volume Meter E4 Used for Measuring Samples from 0 to 250 ml.

and the wall of the tube. The ball spreads the material as it flows from the orifice in *1* so that it falls evenly over the cross-sectional area of the graduated cylinder *5*.

4. Lower support bracket for volume meter and valve rod *8*.

5. 250-ml. graduated glass cylinder, approximately 1.437 in. in inside diameter. Meaured granular material (gas mask canister adsorbent) is seen in the lower portion of cylinder.

6. Wooden frame to which volume meter is attached.

7. Handle for opening valve *9*.

8. Valve rod for transmitting motion from handle *7* to valve *9*.

9. Swinging type shutoff valve for controlling flow of material from hopper *1*. This valve is normally held closed by a tension spring.

In order to measure the volume of a sample by means of the volume meters described herein, the sample is poured into the hopper at the top of the meter, the slide valve at the top of the meter is opened, and the sample permitted to discharge into the graduate. The volume is then read to the nearest milliliter and the sample is discharged by opening the slide valve at the bottom of the graduate when using the E2R3 meter and by dumping the contents from the graduate when using the E4 meter. Specific quantities of material can be measured out by placing a supply of the desired material in the hopper and controlling the quantity fed into the graduate by means of the valve located below the hopper.

To determine the bulk density, the sample is first dried in an oven at a temperature of 150 C. for several hours. Materials that would be damaged by drying at 150 C. must be dried over a longer period of time at a lower temperature. The material should be spread out in layers approximately 0.5 in. thick during the drying period. Next, the volume of a weighed sample is determined as above, preferably using a fairly large sample in order to minimize the effect that a slight error in reading or weighing would have on the accuracy of the bulk density determination:

$$\text{Bulk density} = \frac{\text{weight of sample}}{\text{volume of sample}}$$

In the determination of percentage of voids existing between granules in packed materials, the bulk density is first determined as above and then the true density of the material is determined by any approved method:

$$\text{Percentage of voids} = \frac{\text{true density} - \text{bulk density}}{\text{true density}} \times 100$$

If the granular material on which the percentage of voids determination is to be made is porous, such as gas mask canister charcoal, pumice, etc., a material with solid granules (such as sand) having approximately the same mesh distribution and shape will have to be substituted in order to make the percentage of voids determination.

Discussion

A dispersal head is employed to spread the falling granular material so that it falls evenly over the cross-sectional area of the graduated cylinder. This insures that the surface of the measured sample will be level, thus facilitating accurate reading of the volume. Another purpose of the dispersal head is to reduce the head required to secure maximum packing. Tests on the E2R3 meter have shown that without use of the dispersal head, 7 ft. free fall of the granules was required to secure maximum packing. Apparently this distance was needed for the stream of granules leaving the orifice to expand gradually to a diameter equalling that of the graduated cylinder. Dispersal heads containing 1, 2, 3, and 4 screens were tested. Three screens were found sufficient to give maximum packing with minimum height of free fall. A number of different dispersal heads were tried during the course of experimental work on the E2R3 meter. The screen type was found to be the simplest and most effective. However, with meters having dispersal heads of 1.5 in. inside diameter and smaller, the screens were unsatisfactory in that they tended to become clogged. A cross formed by two 0.62-in. diameter wires was also tried as a dispersal head for the E4 meter, but it was abandoned because it also tended to become clogged. A steel ball was found to be satisfactory for spreading the material in the E4 meter.

Experimental results showed that, using the E2R3 meter with a material having a bulk density of 0.6 g. per ml. or greater, the density of packing increased with increase in height of free fall until a height of approximately 2 ft. was reached.

The effect of varying the diameter of the measuring cylinder on volume measurements was shown by measuring out ten samples of 100 ml. each on meter E2R3 and then measuring the same samples on the other meters. Readings obtained on meter E4 correlated exactly with those obtained on meter E2R3, but meter E3 gave readings of 2 to 3 ml. (average of 2.6 ml.) higher. Since meter E3 has the smallest diameter of measuring cylinder, the higher readings obtained thereon are believed due to "wall effect."[6] By "wall effect" is meant the increased proportion of free space or voids next to the container surface compared to the main part of the bed. This ratio of free space to sample volume, or wall area to sample volume, increases with decrease in diameter of the measuring graduate used. The magnitude of this increase in meters E3 and E4 over that of E2R3 is shown in Table I.

[6] C. C. Furance, "Flow of Gases through Beds of Broken Solids," Bulletin 307, 1928, U. S. Dept. of Commerce, Bureau of Mines, U. S. Govt. Printing Office, Washington, D. C., 1929.

TABLE I.—COMPARATIVE CRITICAL DIMENSIONS OF VOLUME METERS.

Meter	Diameter		Area, sq. cm.	Height for 100 ml., cm.	Area of Wall for 100-ml. Absorbent, sq. cm.	Increase in Wall Area, per cent[a]	Height of Free Fall
	cm.	in.					
E2R3....	5.87	2.312	27.08	3.69	68.11	0	2 in.
E4.....	3.64	1.437	10.45	9.57	109.68	61	2 ft.
E3.....	2.54	1.0	5.07	19.73	157.46	131	2 ft.

[a] Increase in wall area with the E2R3 meter taken as 100 per cent.

Because of the higher readings given by the E3 meter it was abandoned. However, since the results obtained on the E3 meter were fairly uniform, it is assumed that meters with small size measuring cylinders could probably be built, calibrated, and the readings corrected to correlate with those obtained on meters E2R3 and E4.

Meter E4 has a smaller measuring cylinder than the E2R3, but it was made to correlate with it exactly by increasing the height of free fall to the value required to give maximum packing, which compensated for the difference in diameter of measuring cylinders. Volume meter E4 is entirely satisfactory for measuring volumes within its range and should be used for those below the minimum range of meter E2R3, namely, 100 ml.

If meters having measuring cylinders of greater diameter than that used for meter E2R3 were constructed, it is probable that slightly denser packing would be obtained.

The successful operation of the volume meters described herein depends on dropping the material that is being measured into the graduate at a slow rate of flow through a dispersal head which scatters the granules so that they fall evenly over the cross-sectional area of the graduate. In order to obtain maximum packing of material, sufficient head, that is, height of free fall or the distance between the lower most portion of the dispersal head and the top of the graduate, must be provided. When measuring gas mask canister charcoal, which has a bulk density of 0.4 to 0.7 g. per ml., a head of approximately 2 ft. is required as shown by the lower volume readings obtained at that height. Also this same head was found sufficient for maximum packing of lead shot having a diameter of 0.05 in. and a bulk density of 6.98 g. per ml. Meter E2R3 has a head of 2 in. and meter E4, 2 ft. The increased height of the E4 meter was provided in order to compensate for slightly higher readings (less dense packing) obtained therewith when using a 2-in. head. This was done so that correlation could be obtained between the two meters.

The meters are based on the principle that the impact of the falling particles tends to impart a movement to the particles in the surface layer of the material being collected. This movement aids in orienting the granules so that they fit closely together into a minimum space. (A similar principle in so far as orientation is concerned is involved when packing materials into a minimum space in packaging containers by the conventional mechanical vibration method which is widely used commercially.) The particles being measured remain in motion after they fall into the graduate until they are approximately 0.1 in. below the surface of the material which is being measured and of which they form a part. This can be demonstrated by preparing a mixture of black and white materials, such as charcoal and soda lime, and pouring it into the volume meter. The materials can be observed moving about on and below the immediate surface of the mass as long as material is still falling. It is assumed that the energy required to cause the granules to move about and orient themselves is acquired during their free fall in which it is considered that they achieve sufficient momentum to give maximum packing. Experience has shown that with gas mask charcoal having a bulk density of 0.4 to 0.7 g. per ml. increasing the height of free fall beyond 2 ft. does not appreciably increase the density of packing. This height is also sufficient for maximum packing of very heavy materials such as lead spheres as mentioned above.

In order to obtain maximum packing of the sample mass when using the volume meter principle, it is necessary to regulate the rate of flow of material into the graduate. If the rate of feed is too fast, the movement of the surface granules is arrested by the weight of succeeding granules before they can complete their orientation. This prevents maximum packing. Experimental tests have shown that, within limits, the slower the granular materials are fed into the graduated cylinder the denser is the packing obtained. However, extreme slow feeds are disadvantageous in that the smaller orifices used to decrease speed of filling are apt to clog. An orifice of 0.5-in. diameter was selected as standard for all meters as it gave reproducible readings and would pass continuously without clogging the largest mesh size granular material (6–20 U. S. standard sieve scale) used in gas mask canisters.

It is believed that the method of obtaining packing of granular materials by dropping the granules from a height, at a slow rate of feed, has an effect similar to that obtained by tamping.[4]

Comparative Results by Various Methods

The results obtained by the first method used by the Chemical Corps to determine volume (described in the introduction), by pouring through a funnel, were unsatisfactory in that it gave the least dense packing of the various methods used, as shown by the high readings in Table II, and the density of packing varied with the diameter of the funnel spout. Due to the slower filling, the packing becomes better as the diameter of the funnel spout is decreased. (This principle, whereby increased packing results from decreased filling speed, is used in construction of the volume meters described in this article.) Also extreme care must be exercised after pouring the material into the graduate as a slight jar will cause the material to settle considerably, thus introducing an error in the readings. In addition, this method does not pack the material nearly as densely as is accomplished by the canister filling machines. A method that gives density of packing which correlates with that achieved by the canister filling machines is desired.

The second method used by the Chemical Corps to determine volume of granular materials (described in the introduction)—tapping the graduate against a solid surface—was unsatisfactory in that it required considerable time, was awkward in operation, and, as shown in Table II, gave readings which may vary considerably with different operators.

Samples containing 500 ml. each were measured out on volume meter E2R3 and then compared by the hand jigging method and also by carefully pouring the same samples loosely into a graduate. A comparison of the results in Table II shows that the volume meter gave much denser packing than the other methods. No other standard was available for checking the performance of this meter. Accuracy and reproducibility of results

TABLE II.—COMPARISON OF VARIOUS VOLUME-MEASURING TECHNIQUES.

Sample	By Pouring Directly into the Graduate through a Funnel		Hand Jigging Operator No. 1, ml.	Hand Jigging Operator No. 2, ml.	Volume Meter E2R3, ml
	ml.[a]	ml.[b]			
No. 1	588	585	523	545	500
No. 2	589	583	525	550	500
No. 3	588	584	523	555	500
No. 4	590	585	525	545	500
No. 5	590	584	528	543	500
No. 6	588	585	530	550	500
No. 7	589	583	531	548	500
No. 8	590	585	530	550	500
No. 9	590	585	526	552	500
No. 10	589	584	527	542	500

Note.—These tests were made with dry charcoal granules of 12 to 30 mesh (U. S. Standard sieve scale) having a bulk density of 0.6 g. per ml. as determined by volume meter E2R3.

[a] The funnel had a 1.968-in., inside diameter, spout.

[b] The funnel had a 0.875-in., inside diameter, spout.

were determined by making a number of repeated readings on various samples. It was found that volume meter measurments were reproducible within the limit of error of reading, while the other methods of measuring volume were subject to considerable variation or error.

The accuracy and reproducibility of readings obtained on volume meters E3 and E4 were checked against volume meter E2R3. Meters E4 and E2R3 gave identical readings. As stated before in this article, meter E3 did not give as dense packing as E2R3 and E4 and for this reason was abandoned.

The method used by the Chemical Corps for determining bulk density (described in the introduction) prior to development of the volume meters, namely, by pouring the material very slowly into a cylinder, was found satisfactory but had the disadvantage of requiring a fair amount of time and the use of a sensitive balance for weighing the small amount of adsorbent used for the test.

Tensile Stress-Strain Relationships of Laminated Plastics for Small Strains

By J. J. Lamb[1] and B. M. Axilrod[1]

SYNOPSIS

Tensile stress-strain data were taken on six representative plastic laminates using the Tuckerman strain gage for the first 0.5 per cent strain. The materials investigated were a glass-fabric polyester laminate and asbestos-fabric, high-strength-paper, and cotton-fabric phenolic laminates.

A parabolic equation was found to fit the stress-strain data at small strains better than a linear relationship. The initial modulus of elasticity determined by the parabolic equation was 2 to 8 per cent greater than the modulus obtained by the linear equation.

The use of the proportional limit is to be avoided since the determination of this quantity is affected by the precision of the equipment, the method of analyzing the data, and other variables. The use of secant moduli of elasticity for one or more stress ranges or strain ranges is recommended rather than attempting to obtain the initial modulus of elasticity.

THE purpose of this investigation was to obtain more precisely the tensile stress-strain characteristics of typical laminates for small strains, to determine empirical equations to fit the data, and to consider the suitability of terms usually employed to describe the tensile stress-strain properties of laminated plastics.

DEFINITIONS FOR STRESS-STRAIN PROPERTIES

There has been a diversity of terms used to designate the stress-strain relationship in the reporting of strength values for plastic laminates. Some workers have placed emphasis on an initial modulus of elasticity and offset yield stresses based on the initial modulus of elasticity. Others prefer concepts which are related to the usable portion of the stress-strain curve and determine a secant modulus of elasticity based on strain or on a stress which is a definite fraction of the tensile strength.

Review of Present Practices:

The terms used to define some properties of the stress-strain curve of plastics as given in A.S.T.M. Tentative Method of Test for Tensile Properties of Plastics (D 638–46T)[2] and in the Federal Specification for test methods for organic plastics[3] seem to have been influenced by the terms used in the testing of metals. This is shown by the emphasis placed on the initial portion of the stress-strain curve. A.S.T.M. Method D 638 advocates the use of an initial modulus of elasticity and offset yield stresses. In the Federal Specification L-P-406a, Method No. 1011 for "Tensile Properties of Plastics" defines an initial modulus of elasticity, secant moduli of elasticity at arbitrary strains, tangent and offset proportional limits, offset yield strength, and yield strengths for specified extensions under load.

Different combinations of these terms have been used in reporting the mechanical properties of plastic laminates. Fuller (1)[4] has used the initial modulus of elasticity, both tangent and 0.01 per cent offset proportional limits, and 0.20 per cent offset yield stress. Field (2) has reported values of the secant modulus of elasticity for a strain range of 0 to 0.7 per cent and has defined the yield strength as being equal to the stress at either 0.7 per cent strain or 76 per cent of ultimate stress, whichever is less. Meyer and Erickson of the Forest Products Laboratory (3), in describing the mechanical properties of high-strength paper laminates, have reported values for initial modulus of elasticity, proportional limit, yield strengths at 0.2 and 0.7 per cent strain offsets, and secant modulus of elasticity at 0.2 per cent strain offset. Findley and Worley (4) reported an initial modulus of elasticity and 0.05 and 0.20 per cent offset yield stresses in tension and compression tests on some of the same materials tested by the authors.

The use of the term "yield strength" implies a permanent set in the material (see A.S.T.M. Definitions of Terms Relating to Methods of Testing (E 6–36)).[5] How-

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] National Bureau of Standards, Washington, D. C.

[2] 1946 Book of A.S.T.M. Standards, Part III-B, p. 819.

[3] Federal Specification for Plastics, Organic: General Specifications, Test Methods (L-P-406a), Government Printing Office, January 24, 1944.

[4] The boldface numbers in parentheses refer to the list of references appended to this paper.

[5] 1946 Book of A.S.T.M. Standards, Part III-B, p. 487.

ever, very little is known concerning the relation of permanent set to strain in plastic laminates. Marin (5) has shown hysteresis loops for five of the laminates treated in this paper. For strains of approximately 1 per cent, four of the laminates—the high-strength paper, the rayon-fabric, and the two grade C cotton-fabric laminates—had permanent sets of only about 50 per cent of their largest offset from the initial modulus. The lack of more specific data on the relation of per cent offset to permanent set for the plastic laminates has led the authors to define an offset stress with reference only to the geometry of the stress-strain line rather than to speak of a yield strength at an offset strain.

Definitions Used in This Report:

The *tangent modulus of elasticity*, E_T, at a given stress is defined as the slope of the tangent to the stress-strain curve at that stress.

The *initial modulus of elasticity*, E, is defined as the tangent modulus of elasticity at zero stress. (This definition differs from those given in Federal Specification L-P-406a and in the A.S.T.M. Method D 638, in both of which the initial modulus of elasticity is defined as the slope of the straight portion of the stress-strain curve beginning at zero stress.)

The *secant modulus of elasticity* for a range of stress, zero to S_1, is defined as the slope of the secant line intersecting the stress-strain curve at zero stress and at a stress S_1.

The *secant modulus of elasticity* for a range of strain, zero to ϵ_1, is defined as the slope of the secant line intersecting the stress-strain curve at zero strain and at a strain ϵ_1.

An *offset stress* for N per cent strain is defined as the stress at which a line parallel to the initial modulus of elasticity, but offset by N per cent strain, intersects the stress-strain curve.

Stress-Strain Equations:

In considering the type of equation used to fit the tensile stress-strain data of plastics, it is useful to review the work done in metals. Recently it has become generally recognized that Hooke's law is only an approximate representation of the stress-strain diagram for metals. Osgood (6) states that "whether it (Hooke's law) is exact even for values of strain approaching zero is at best doubtful." Sayre (7) has shown that for many metals the stress-strain line is probably curved throughout its whole length, and can be represented even at small strains by the equation:

$$E_T = E_0 - KS$$

where:

E_T = the tangent modulus of elasticity,
E_0 = the initial modulus of elasticity,
K = a constant, and
S = the stress.

Equations to fit the stress-strain diagram of metals have been proposed by many investigators. In a review paper Osgood (6) explains that the first terms of a series, such as used by Sayre (7), can be made to fit a limited portion of the stress-strain curve. By the use of four or five terms in such a series a good fit can be made to a large part of the stress-strain curve of some materials. Osgood, however, has emphasized that the most practical equation would be one that had only a few parameters which could easily be determined. Together with Ramberg (8), he has proposed the equation

$$\epsilon = \frac{S}{E} + K\left(\frac{S}{E}\right)^n$$

which seems to be particularly applicable when the stress-strain curve shows a gradual yielding rather than a sharp yield point. In the above equation E is the initial modulus of elasticity (as defined in this paper) and K and n are the intercept and the slope, respectively, of the plotted equation:

$$\log\left(\epsilon - \frac{S}{E}\right) = \log K + n \log \frac{S}{E}$$

In the present investigation three different methods for determining the modulus of elasticity of six different types of plastic laminates are compared. The methods chosen are based on (1) Hooke's law, (2) the empirical equation proposed by Ramberg and Osgood, and (3) a secant modulus of elasticity based on a range of stress.

Materials Tested

The materials selected for testing included an asbestos-fabric grade

TABLE I.—DESCRIPTION OF MATERIALS.

N.B.S. Designation	Type of Laminate	Density, g. per cu. cm.	Thickness Average, in.	Manufacturer	Resin		Reinforcement					Molding Conditions			
					Type	Content by Weight, per cent	Type	Thread Warp	Count Filling	No. of Plies	Ply Arrangement	Pressure, psi.	Temperature, deg. Fahr.	Time of Heating, min.	Time of Cooling, min.
K1	Grade AA[a] asbestos-fabric phenolic	1.50	0.15	Synthane Corp.	Bakelite 2427	47	Asbestos fabric, 18 oz. per sq. yd.	18	16	5	Parallel	1800	340 ± 20	50	20
S1	High-strength-paper phenolic	1.42	0.12	Consolidated Water Power and Paper Co.	Bakelite 16526	30	High-strength Mitscherlich Paper, 32.5 lb. per ream of 480 sheets, 24 by 36 in.	...	...	27 per 0.060-in. thickness	Cross	250	310 ± 10		
V1	Low-pressure[a] grade C phenolic	1.27	0.15	Synthane Corp.	Bakelite BV-16887	51	Army Duck 10.38 oz. per sq. yd.	38	50	7	Cross	180	320	50	
W1	High-pressure grade C phenolic	1.36	0.14	Synthane Corp.	Bakelite BV-1112	47	Army Duck 10.38 oz. per sq. yd.	38	50	7	Cross	1800	320	50	
Z1	Rayon-cotton-fabric phenolic	1.37	0.16	Formica Insulation Co.	Ironsides 91-L	37–40	Fortisan WE-3975, Celanese Corp. of America 3/1 Twill 12.5 oz. per sq. yd.	75 Rayon	12 Cotton	7	Cross	1100	310 ± 10	20	20
AG1	Glass-fabric unsaturated-polyester	1.83	0.13	Army Air Forces Technical Service Command	Plaskon 911	43	Fiberglas ECC-11-112, Owens-Corning Fiberglas Corp.	38	38	50	Parallel	40	200	60	

[a] The grade AA and grade C materials are described in A.S.T.M. "Tentative Specification for Laminated Thermosetting Materials" (D 709-47 T) 1947 Supplement to Book of A.S.T.M. Standards, Part III, p. 20.

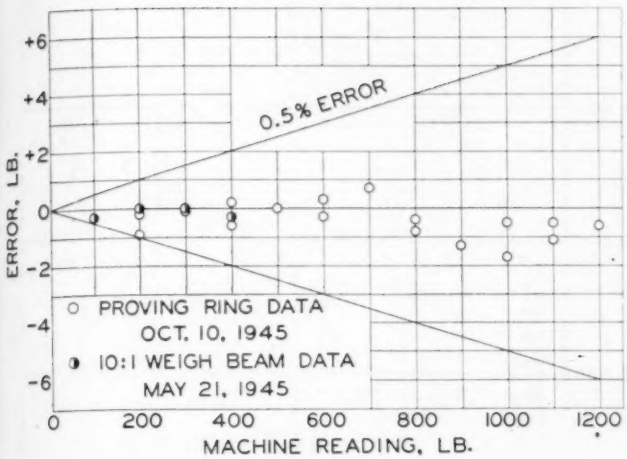

Fig. 1.—Calibration of 1200-lb. Scale of the 2400-lb. Southwark-Emery Testing Machine, N.B.S. No. 15914.

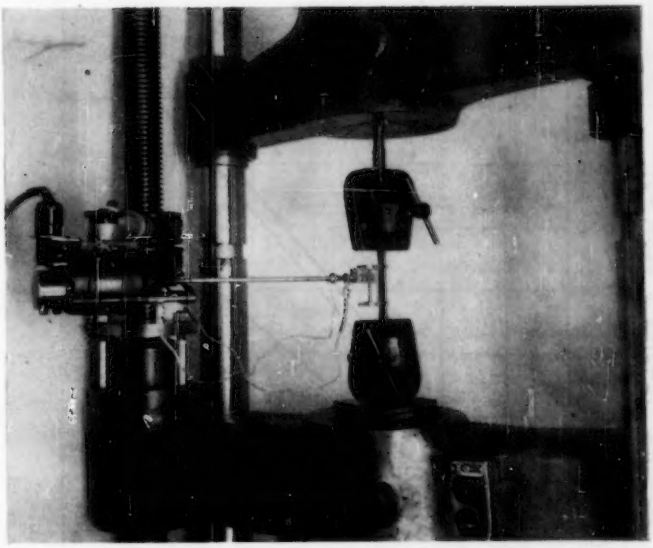

Fig. 2.—Tension Specimen in the Testing Machine with the Southwark-Peters Extensometer Attached.

AA phenolic laminate, a high-strength-paper phenolic laminate, a rayon-fabric phenolic laminate, two experimental grade C cotton-fabric phenolic laminates made with high and low pressure, respectively, and a glass-fabric polyester laminate. The grade AA and grade C materials are of the type described in A.S.T.M. Tentative Specification for Laminated Thermosetting Materials (D 709–47 T).[6] A complete description of the laminates is given in Table I. These six laminates were included in the investigation reported by Lamb, Albrecht, and Axilrod (9, 10) and, with the exception of the asbestos-fabric phenolic laminate, were also tested by Marin (5) and by Findley and Worley (4).

Test Equipment and Procedure

Tension tests to obtain stress-strain curves to failure were made on five specimens of each of the six laminates. Tension tests with Tuckerman optical strain gages to approximately 0.5 per cent strain were made on three specimens of each of the six laminates.

The tension tests to failure were made on the 2400 and 12,000-lb. ranges of a 60,000-lb. capacity Baldwin-Southwark hydraulic universal testing machine. The tension tests with the Tuckerman gages were made on the 1200-lb. range of a 2400-lb. capacity Baldwin-Southwark hydraulic universal testing machine which had been calibrated with a Morehouse proving ring about one month before the tests. The calibration curve is shown in Fig. 1.

The autographic strain gage used in the tension tests to failure was a nonaveraging Southwark-Peters plastics extensometer, Model PS-6 (Fig. 2), with a 2-in. gage length and a strain magnification of 400. This extensometer, with a strain range of 10 per cent, separates into two parts and can be left on the specimen until failure. The relative rate of crosshead motion was 0.05 in. per min. in tests with this extensometer.

The Tuckerman optical strain gage (11) has been used extensively for the static testing of metals when precise strain data were desired (12). The strain gages used in these tests had 0.4-in. lozenges and measured a total of 0.5 per cent strain in a 2-in. gage length. These gages were calibrated with an interferometer (13) about six months before the tests were made. The Tuckerman gage is known to be linear (13) and an error in calibration would cause insignificant errors in relative values of moduli of elasticity and offset stresses.

The Tuckerman gages were mounted on opposite faces of the specimen (Fig. 3) and the readings were averaged. A crosshead speed of 0.005 in. per min., one-tenth of the speed generally used in this laboratory for the tension testing of plastics with strain gages, was used in order that the strain gage could be read to 0.001 per cent strain. Strain readings were taken at loads spaced to obtain thirty pairs of readings up to approximately 0.35 to 0.45 per cent strain.

In general, the tension testing for both sets of specimens was done in accordance with Method No. 1011 of Federal Specification L-P-406a.[3] The specimen dimensions were those for the type 1 specimen of Method

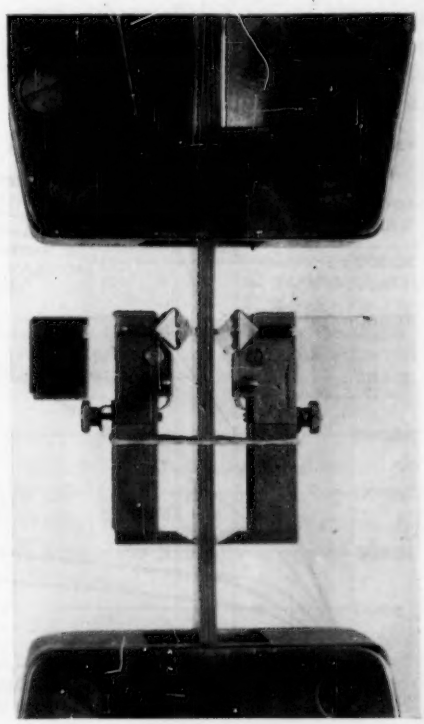

Fig. 3.—Tension Specimen in the Testing Machine with Tuckerman Strain Gages Attached. A 45 deg.–45 deg.–90 deg. Prism Is Cemented to Each Gage to Permit the Operator to Read Both Gages from the Same Position.

[6] 1947 Supplement to Book of A.S.T.M. Standards, Part III-B, p. 56.

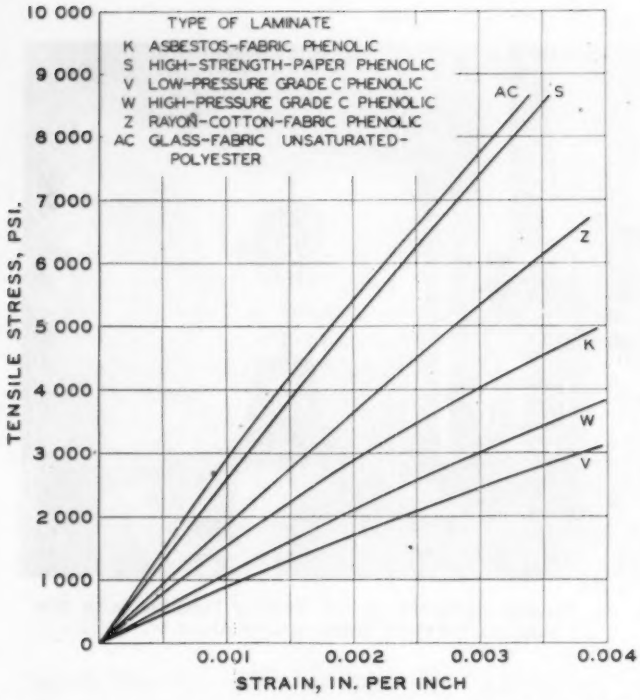

Fig. 4.—Average Tensile Stress-Strain Curves for $\frac{1}{8}$ in. Thick Laminates from Measurements Made with the Tuckerman Strain Gage.

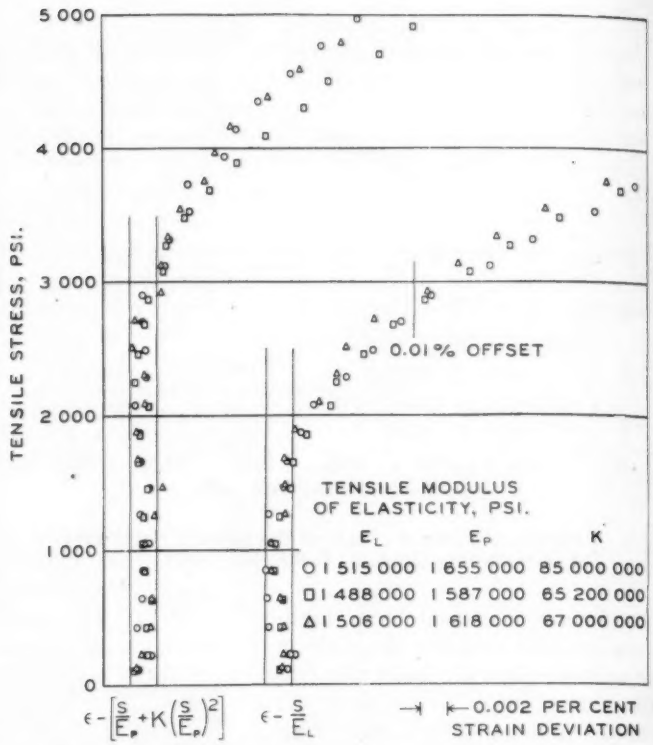
TENSILE STRESS, PSI.
0.01% OFFSET
TENSILE MODULUS OF ELASTICITY, PSI.
E_L E_P K
O 1 515 000 1 655 000 85 000 000
□ 1 488 000 1 587 000 65 200 000
Δ 1 506 000 1 618 000 67 000 000
0.002 PER CENT STRAIN DEVIATION

Fig. 6.—Tensile Stress-Strain Deviation Curves for Grade AA Asbestos-Fabric Phenolic Laminate, K1. (0.001 per cent Strain Is the Least Count of the Strain Gage.)

No. 1011 with a length of 9 in., a width of 0.75 in. and a reduced section of 2.2 in. length and 0.5 in. width.

The cotton-fabric laminates were loaded to about 300 lb. and the paper- and glass-fabric laminates to about 650 lb. According to the calibration curve the error in load in this range of loading is less than 1 lb.; the corresponding maximum error in stress would be 13 to 16 psi., depending on the thickness of the specimen. Thus a 1-lb. error in reading the load would be equivalent to an error of about 0.001 per cent strain for the cotton-fabric laminates. Since the other materials have higher moduli of elasticity, the error in strain equivalent to the 1-lb. load error would be proportionately less for them.

A 0.001 per cent offset stress is reported even though the possible total error in load and strain gage readings was equivalent to an error greater than 0.001 per cent strain in some instances.

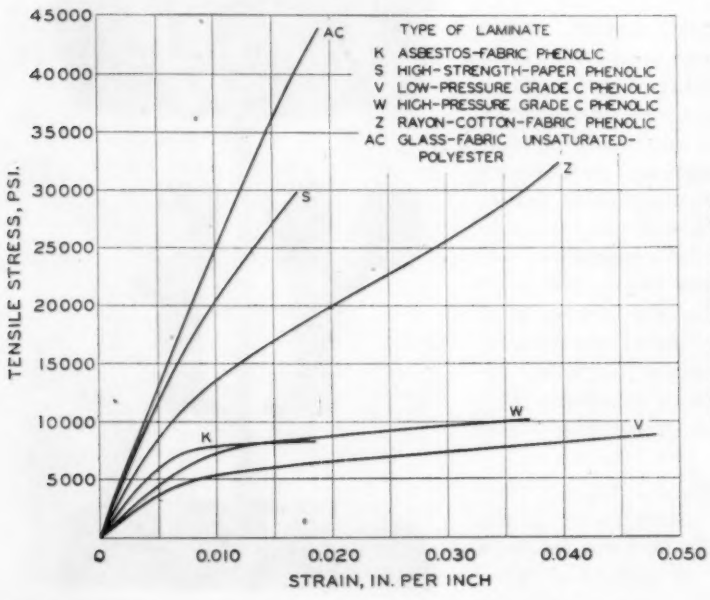

Fig. 5.—Average Tensile Stress-Strain Curves for $\frac{1}{8}$ in. Thick Laminates at 77F.

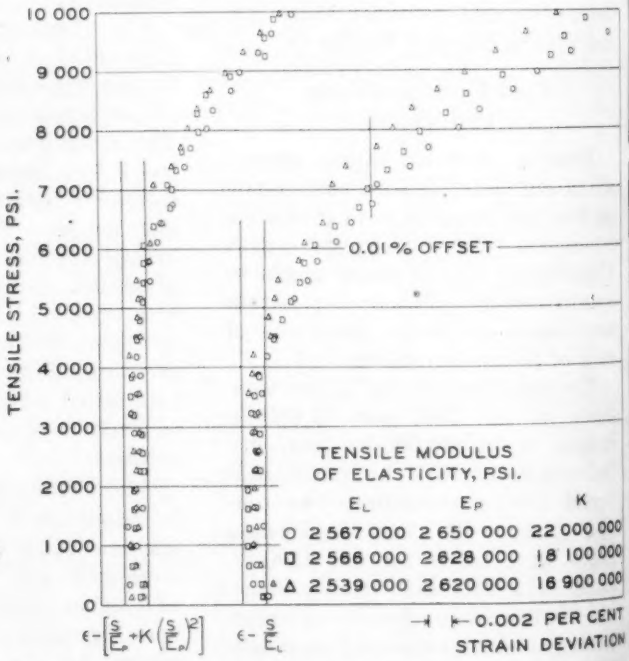
TENSILE STRESS, PSI.
0.01% OFFSET
TENSILE MODULUS OF ELASTICITY, PSI.
E_L E_P K
O 2 567 000 2 650 000 22 000 000
□ 2 566 000 2 628 000 18 100 000
Δ 2 539 000 2 620 000 16 900 000
0.002 PER CENT STRAIN DEVIATION

Fig. 7.—Tensile Stress-Strain Deviation Curves for High-Strength-Paper Phenolic Laminate, S1 (0.001 per cent Strain Is the Least Count of the Strain Gage.)

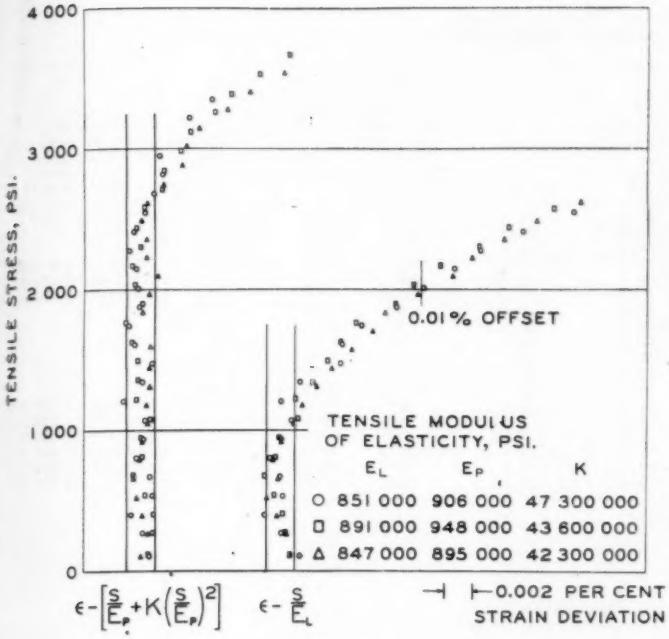
TENSILE STRESS, PSI.
0.01 % OFFSET
TENSILE MODULUS OF ELASTICITY, PSI.
E_L E_P K
O 851 000 906 000 47 300 000
□ 891 000 948 000 43 600 000
Δ 847 000 895 000 42 300 000
0.002 PER CENT STRAIN DEVIATION

Fig. 8.—Tensile Stress-Strain Deviation Curves for the Low-Pressure Grade C Phenolic Laminates, V1. (0.001 per cent Strain Is the Least Count of the Strain Gage.)

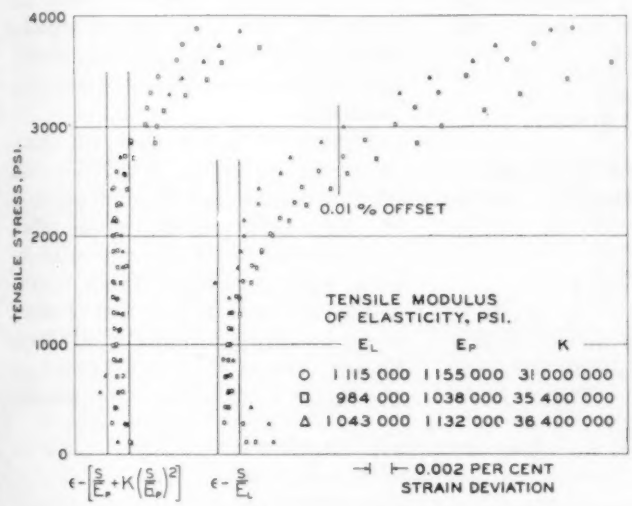
TENSILE STRESS, PSI.
0.01 % OFFSET
TENSILE MODULUS OF ELASTICITY, PSI.
E_L E_P K
O 1 115 000 1 155 000 31 000 000
□ 984 000 1 038 000 35 400 000
Δ 1 043 000 1 132 000 36 400 000
0.002 PER CENT STRAIN DEVIATION

Fig. 9—Tensile Stress-Strain Deviation Curves for the High-Pressure Grade C Phenolic Laminate, W1. (0.001 per cent Strain Is the Least Count of the Strain Gage.)

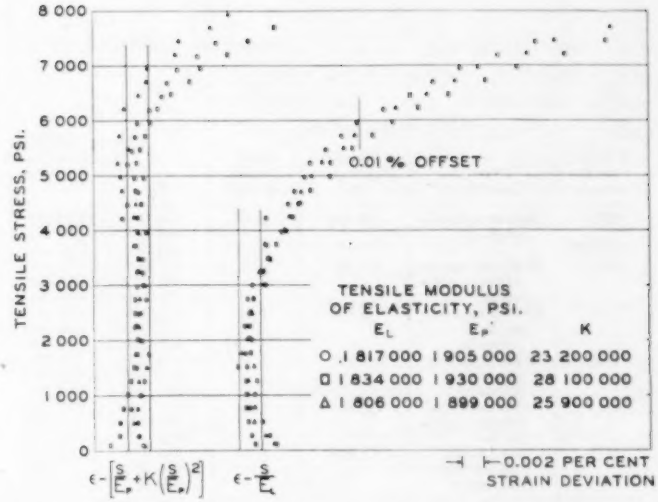
TENSILE STRESS, PSI.
0.01 % OFFSET
TENSILE MODULUS OF ELASTICITY, PSI.
E_L E_P K
O 1 817 000 1 905 000 23 200 000
□ 1 834 000 1 930 000 28 100 000
Δ 1 806 000 1 899 000 25 900 000
0.002 PER CENT STRAIN DEVIATION

Fig. 10.—Tensile Stress-Strain Deviation Curves for the Rayon-Cotton-Fabric Phenolic Laminate, Z1. (0.001 per cent Elongation Is the Least Count of the Strain Gage.)

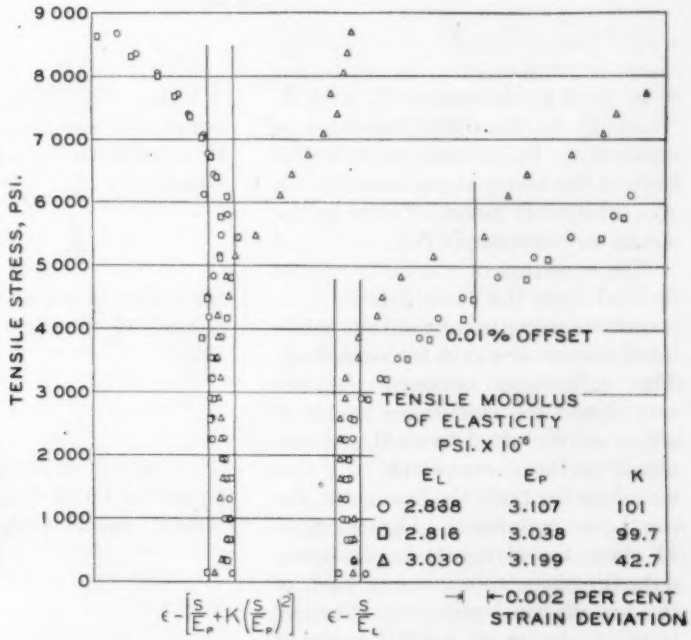
TENSILE STRESS, PSI.
0.01 % OFFSET
TENSILE MODULUS OF ELASTICITY PSI. X 10^6
E_L E_P K
O 2.838 3.107 101
□ 2.816 3.038 99.7
Δ 3.030 3.199 42.7
0.002 PER CENT STRAIN DEVIATION

Fig. 11.—Tensile Stress-Strain Deviation Curves for the Glass-Fabric Unsaturated Polyester Laminate, AC 1. (0.001 per cent Strain Is the Least Count of the Strain Gage.)

Stress-Strain Data and Analysis

The stress-strain curves of the six laminates up to 0.4 per cent strain are shown in Fig. 4. Each of these curves is the average of tests on three specimens made with Tuckerman strain gages. These curves are very similar to the initial part of those shown in Fig. 5 which contains the complete tensile stress-strain curves for the six plastic laminates. As noted under "Test Equipment and Procedure," these two sets of curves are plotted from data taken with different strain gages at different speeds of testing.

The method of least squares (14) was used to test two equations for goodness of fit to the experimental stress-strain data corresponding to the initial part of the curve obtained with the optical strain gages.

A straight line

$$\epsilon = a + bs$$

was chosen for the first equation. ϵ is the strain, s the stress, a is the strain at zero stress, and $b = 1/E_L$, where E_L is the modulus of elasticity. For each specimen the first eight to ten points of the stress-strain curve (the first 0.1 per cent strain) were used to determine E_L. Thus, E_L is actually a secant modulus of elasticity.

A parabola

$$\epsilon = a' + b's + c's^2$$

where $b' = 1/E_P$ and $c' = K/E^2_P$ and the other quantities are defined as above, was chosen for the second equation. For each specimen, the first 15 points of the experimental data (the first 0.2 per cent strain)

TABLE II.—TENSILE PROPERTIES OF LAMINATED PLASTICS.

N.B.S. Designation	Type of Laminate	Tensile Strength, psi.	Total Strain, per cent	Tensile Modulus of Elasticity, psi.[a]			K/E_P^2, 10^{-12} in.^{4}/lb.^{2}	Proportional Limit Stress from Linear Relationship, psi.		Secant Modulus of Elasticity for Various Ranges of Stress, psi.		
				E_L	E_P	K		0.001 per cent Offset	0.01 per cent Offset	0 to 2500	0 to 5000	0 to 7500
K1....	Asbestos-fabric phenolic	8 200	1.8	1 515 000	1 655 000	85.3	31.1	1750	2750	1 480 000	1 270 000	
				1 488 000	1 587 000	65.2	25.9	1650	2800	1 450 000	1 250 000	
				1 506 000	1 618 000	66.4	25.6	1850	2900	1 490 000	1 280 000	
S1.....	High-strength-paper phenolic	29 700	1.7	2 567 000	2 650 000	22.0	3.13	4000	6800	2 590 000	2 540 000	2 430 000
				2 566 000	2 628 000	18.1	2.62	4000	7000	2 570 000	2 530 000	2 470 000
				2 539 000	2 620 000	16.9	2.46	4600	7600	2 580 000	2 540 000	2 470 000
V1.....	Low-pressure grade C phenolic	8 900	4.8	851 000	906 000	47.2	57.6	1300	2000	810 000		
				891 000	948 000	43.6	48.5	1200	2050	850 000		
				847 000	895 000	42.3	52.8	1100	1950	800 000		
W1....	High-pressure grade C phenolic	10 300	3.7	1 115 000	1 155 000	31.0	23.2	1500	2700	1 090 000		
				984 000	1 038 000	35.4	32.9	1450	2500	960 000		
				1 043 000	1 132 000	36.4	28.4	1700	2950	1 060 000		
Z1.....	Rayon-cotton-fabric phenolic	32 400	4.0	1 817 000	1 905 000	23.2	6.40	3300	5900	1 850 000	1 800 000	1 750 000
				1 834 000	1 930 000	28.1	7.55	3000	5650	1 850 000	1 820 000	1 720 000
				1 806 000	1 899 000	25.9	7.17	3100	5800	1 820 000	1 770 000	1 680 000
AC1...	Glass-fabric unsaturated-polyester	43 900	1.9	2 868 000	3 107 000	101.3	10.5	2900	4700	2 920 000	2 840 000	2 490 000
				2 816 000	3 038 000	99.7	10.8	2900	4400	2 830 000	2 610 000	2 420 000
				3 030 000	3 199 000	42.8	4.17	3900	5700	3 090 000	2 980 000	2 780 000

[a] The tensile moduli of elasticity were calculated from the following equations:

Linear relationship

$$\epsilon = \frac{s}{E_L}$$

Parabolic relationship

$$\epsilon = \frac{s}{E_P} + K\left(\frac{s}{E_P}\right)^2$$

where:

ϵ = strain,
s = stress,
E_L = initial modulus of elasticity from linear equation,
E_P = initial modulus of elasticity from parabolic equation, and
K = a constant.

were used to determine E_P and K. Thus, E_P is the initial modulus of elasticity. In the computations for both of the above equations all error was arbitrarily assumed to be in the strain measurement (14).

The modulus of elasticity values derived from the least-squares computations were used to obtain calculated values of strain for each load. The differences between the observed and the calculated values of strain were plotted to yield a stress-strain deviation curve (15, 12); this was done for both the linear and the parabolic equations. Figures 6 to 11 show the stress-strain deviation data for three specimens of each of the six plastic laminates. Vertical lines are drawn at ±0.001 per cent strain deviation (the least count of the strain gage) to indicate the degree to which the assumed equation fits the stress-strain data (15).

The moduli of elasticity (E_L and E_P), 0.001 and 0.01 per cent offset stresses for the linear equation, and constants for the parabolic equation are given in Table II. For all six materials, the value of E_P is greater than E_L. The percentage difference between these two moduli of elasticity varies from 2 per cent for the high-strength-paper laminate to nearly 8 per cent for the glass-fabric laminate. The percentage difference between the two values seems to be a function of the value of K in the parabolic equation.

Since the tensile stress-strain curve of these plastic laminates can be represented at low stresses by the equation

$$\epsilon = \frac{S}{E_P} + K\left(\frac{S}{E_P}\right)^2,$$

the value of an offset stress can be computed directly from the equation

$$\epsilon - \frac{S}{E_P} = K\left(\frac{S}{E_P}\right)^2$$

This has been done for $\epsilon-(S/E_P)$ equal to 0.001 and 0.01 per cent strain, respectively. These computed values of offset stresses are plotted in Fig. 12 along with the values of the same offset stresses taken from the stress-strain deviation curves based on the linear relationship.

Figure 12 shows that the computed values of the 0.001 per cent offset stress are less than 50 per cent of the values of the same offset stress based on the linear relationship between stress and strain. Values of the 0.01 per cent of offset stress are correspondingly only 70 to 90 per cent of the values based on the linear relationship, the percent-

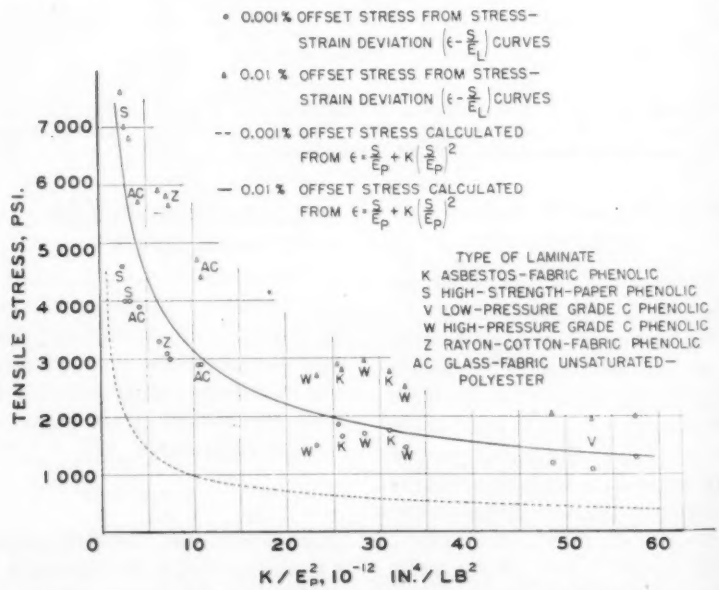

Fig. 12.—Comparison of 0.001 per cent and 0.01 per cent Offset Proportional Limit Stresses from Linear and Parabolic Stress-Strain Relationships.

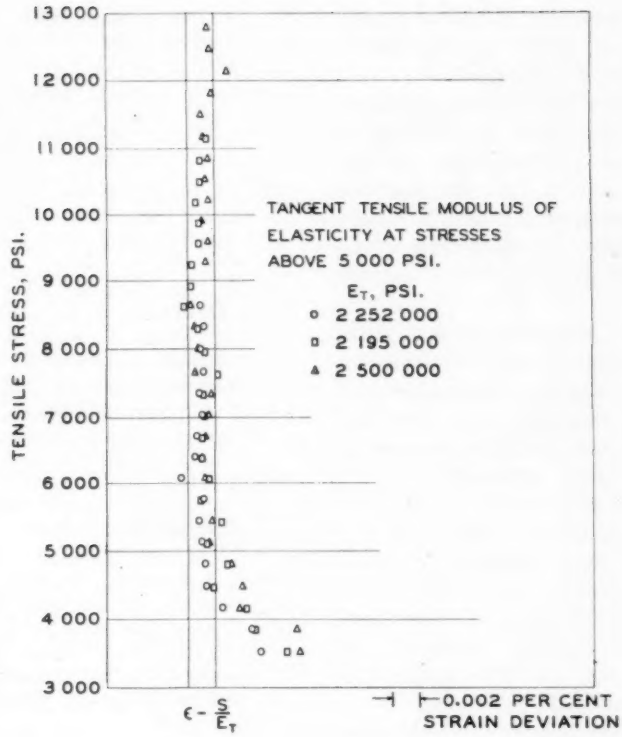

Fig. 13.—Tensile Stress-Strain Deviation Curves for the Glass-Fabric Unsaturated-Polyester Laminate, AC1. (0.001 per cent Strain Is the Least Count of the Strain Gage.)

age difference being greater for larger values of K/E_P^2. The value of K/E_P^2 is the criterion for the deviation of the stress-strain curve from a straight line at small strains. From the values of K/E_P^2 in Table II, it is seen that low values of K/E_P^2 correspond to high values for offset stresses and *vice versa*.

Secant moduli of elasticity for several ranges of stress were computed for each specimen from the original stress-strain data taken with Tuckerman gages and are given in Table II. It is observed that the secant modulus of elasticity for the range of stress 0 to 2500 psi. is greater than E_L for the three laminates with a nominal modulus of elasticity greater than 1,500,000 psi. and less than E_L for the three laminates of lower modulus of elasticity. This is equivalent to a comparison of secant moduli of elasticity for an arbitrary range of stress and for an arbitrary range of strain, since E_L is a secant modulus of elasticity for a strain of 0.1 per cent.

Attempts to fit the Ramberg-Osgood equation

$$\epsilon = \frac{S}{E} + K\left(\frac{S}{E}\right)^n$$

to the data failed when the modulus of elasticity used was the value, E_L, given by the linear equation. When the value of E_P derived from the least-squares parabola was substituted in the Ramberg-Osgood equation and the latter fitted to the data reported herein for strains up to 0.5 per cent, n was found to vary from 1.8 for the cotton-fabric laminates to 2.5 for the high-strength-paper laminate. The Ramberg-Osgood equation could not be fitted to the tensile stress-strain data for the glass-fabric laminate.[7] Some light is shed on this point by further examination of the stress-strain data.

Figures 4 and 5 show that the stress-strain diagram for the glass-fabric laminate is almost straight between about 5000 and 25,000 psi. Stress-deviation calculations were made for each specimen of this laminate based on the tangent modulus of elasticity for the apparently straight portion of the stress-strain diagram and the results plotted in Fig. 13. The stress-deviation diagrams (Fig. 13) indicate that the stress-strain diagram is linear from 5000 to at least 12,000 psi. The tangent modulus of elasticity, E_T, for the linear portion is about 75 per cent of the initial modulus of elasticity, E_P. These results are in agreement with those of Findley and Worley (4) who tested a similar laminate and found "a small change in slope...at about 6000 psi. followed by a straight-line relationship extending nearly to fracture."

[7] Unpublished data of the authors show that the Ramberg-Osgood equation is a good approximation to the compressive stress-strain curves of all these laminates (including the glass-fabric laminate) up to 0.7 per cent strain.

Discussion of Terms and Equations

Offset Yield Stress:

Since least-squares calculations are time consuming, reporting of offset stress data, at least for offsets of the order of 0.001 to 0.01 per cent strain, is not practical for ordinary testing of plastic laminates. Furthermore, as the tensile stress-strain diagram for representative laminates is better fitted by a parabolic law than a linear equation, it seems to the authors that the term offset stress loses much of its significance when applied to plastic laminates.

Proportional Limit:

As the stress-strain data for each of the several types of laminate tested are better fitted by a curve than a straight line, the usage "proportional limit" is of doubtful value. Furthermore, if a plastic should have a linear stress-strain diagram, the determination of the proportional limit is sensitive to many variables (15), such as precision of strain gages and testing machine and the method of analyzing the data (see paragraph on "Offset Yield Stress").

Modulus of Elasticity:

It is proposed that a secant modulus of elasticity be used instead of initial modulus of elasticity in the normal tensile testing of laminates. The initial modulus of elasticity cannot be determined accurately by the procedures ordinarily used in obtaining stress-strain data unless the material obeys Hooke's law for a considerable range of strain. Secant moduli of elasticity, if given for several stress or strain ranges, permit approximate drawing of the stress-strain diagram and should be useful to the designer.

The determination of the secant modulus of elasticity is less sensitive to personal factors, to the linearity and accuracy of the test equipment, and to the method of treating the data than is the determination of the initial modulus of elasticity.

Stress-Strain Equations:

Figures 6 through 11 show that the parabolic relationship in every instance fits the experimental data over a greater range of stress than the linear relationship. The parabolic equation yields an initial modulus of elasticity which is 2 to 8 per cent greater than the modulus of elasticity obtained by the linear equation.

Since it is known that the strain in plastic laminates is a function of time as well as stress (4, 5), it is expected that the modulus of elasticity E_L and the constant K are probably functions of testing speed. Findley (16) in testing cellulose acetate in tension at various rates of straining found that the stress-strain diagram was practically linear up to stresses of 3500 psi. for a jaw separation of 1.9 in. per min. As the speed of testing diminished, the stress-strain diagram became curved at progressively lower stresses until at 0.02 in. per min. jaw separation, curvature was noted below 1500 psi. For thermosetting plastics, and particularly laminates, the effect of speed of testing may be less marked than with cellulose acetate. However, greater speeds of testing will probably result in smaller values for the constant K and less disparity between the values of E_P and E_L.

Conclusions

1. An empirical parabolic expression fits the tensile stress-strain curves of six representative plastic laminates at small strains better than a linear expression.

2. The initial tensile modulus of elasticity obtained by fitting a least-squares straight line to the stress-strain data for the first 0.1 per cent strain was 2 to 8 per cent less than the corresponding value obtained by fitting a least-squares parabola.

3. Offset stress values for strain offsets of 0.001 to 0.01 per cent are sensitive to the test procedure and method of analyzing the data and are not practical to obtain in routine testing of plastic laminates.

4. The use of proportional limit is to be avoided for two reasons. First, the determination of this quantity is affected by the same variables as offset stress for very small strain offset. Second, for laminates such as those tested the stress-strain diagram is not linear.

5. The reporting of secant moduli of elasticity is recommended for routine testing of plastic laminates.

References

(1) F. B. Fuller, "Engineering Properties of Plastics," *Modern Plastics*, Vol. 20, June, 1943, p. 95.

(2) P. M. Field, "Basic Physical Properties of Laminates," *Modern Plastics*, Vol. 20, August, 1943, p. 91.

(3) H. R. Meyer and E. C. O. Erickson, "Factors Affecting the Strength of Papreg. Some Strength Properties at Elevated and Subnormal Temperatures," Forest Products Laboratory Report No. 1521, January, 1945.

(4) W. N. Findley and W. J. Worley, "Mechanical Properties of Five Laminated Plastics," National Advisory Committee for Aeronautics Technical Note No. 1560. (In press.)

(5) J. Marin, "Static and Dynamic Properties of Laminated Plastics for Various Types of Stress," National Advisory Committee for Aeronautics, Technical Note No. 1105, February, 1947.

(6) W. R. Osgood, "Stress-Strain Formulas," *Journal of the Aeronautical Sciences*, Vol. 12, January, 1946, p. 45.

(7) M. F. Sayre, "Laws of Elastic Behavior in Metals," *Transactions*, Am. Soc. Mechanical Engrs., Vol. 56, July, 1934, p. 555.

(8) W. Ramberg and W. R. Osgood, "Description of Stress-Strain Curves by Three Parameters," National Advisory Committee for Aeronautics, Technical Note No. 902, July, 1943.

(9) J. J. Lamb, I. Albrecht, and B. M. Axilrod, "Impact Strength and Flexural Properties of Laminated Plastics at High and Low Temperatures," National Advisory Committee for Aeronautics Technical Note No. 1054, August, 1946.

(10) J. J. Lamb, I. Albrecht, and B. M. Axilrod, "Tensile and Compressive Properties of Laminated Plastics at High and Low Temperatures," National Advisory Committee for Aeronautics, Technical Note No. 1550. (In press.)

(11) L. B. Tuckerman, "Optical Strain Gages and Extensometers," *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part II, p. 602 (1923).

(12) C. S. Smith, "Proportional Limit Tests on Copper Alloys," *Proceedings*, Am. Soc. Testing Mats., Vol. 40, p. 864 (1940).

(13) B. L. Wilson, "Characteristics of the Tuckerman Strain Gage," *Proceedings*, Am. Soc. Testing Mats., Vol. 44, p. 1017 (1944).

(14) A. G. Worthing and J. Geffner, "Treatment of Experimental Data," p. 240, John Wiley and Sons, New York (1943).

(15) L. B. Tuckerman, Discussion of paper by R. L. Templin entitled "The Determination and Significance of the Proportional Limit in the Testing of Metals," *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part II, p. 538 (1929).

(16) W. N. Findley, "Mechanical Tests of Cellulose Acetate," *Modern Plastics*, Vol. 19, September, 1941, p. 57.

Discussion of Paper on the Ignition Temperature of Rigid Plastics[1]

Mr. N. P. Setchkin.[2]—In their paper on Ignition Temperatures of Rigid Plastics E. M. Schoenborn and D. S. Weaver, Jr., have introduced a method for the determination of the ignition properties of plastics in which the furnace temperature is kept constant and well above the ignition of plastics. Wide experience in the determination of the ignition temperatures of various substances including plastics prompts me to submit the following comments on this paper. An examination of Table I of the paper shows excessive variation in the values of the "apparent ignition temperature" of the same material, in spite of the high precision in the locations of the specimen and thermocouples and the special attention given to the extrapolation to the surface temperature. The variation in the values reported for phenolic asbestos paper is 420 F. and for other materials it ranged

[1] E. M. Schoenborn and D. S. Weaver, Jr., "The Ignition Temperature of Rigid Plastics," ASTM Bulletin, Vol. 146, May, 1947, p. 80; Discussion, No. 148, October, p. 86.

[2] Fire Protection Engineer, National Bureau of Standards, Washington D. C.

from 20 to 300 F. According to standard practice at the National Bureau of Standards and in commercial laboratories the maximum deviation in the ignition temperature is usually less than 4 F. Moreover, the minimum values of the apparent ignition temperature for some materials appear unduly low for the conditions of the present tests even with an igniting flame present.

The lowest ignition temperature of cellulose acetate plastic reported by the authors is 184 F. It is doubtful that this material can be ignited at a temperature below the temperature of boiling water. Experiments show that cellulose acetate plastic held 24 hr. in the furnace with constant air temperature around the specimen at 250 F. was neither ignited, nor developed inflammable gas, nor were appreciable changes in the physical state of the material observed, outside of the fact that small bubbles developed inside of the specimen. When the air temperature was increased to 580 F., a sufficient amount of gas was given off to be lighted by the igniter flame and only at the temperature of 842 F. did these gases become self-ignited in the absence of an ignition source. Among the different types of plastic materials, the lowest ignition temperature was obtained for cellulose nitrate at the air temperature of 291 F. A comparison of the reported results with those obtained at the National Bureau of Standards is given in the accompanying Table I.

TABLE I.—COMPARISON OF THE "APPARENT IGNITION TEMPERATURE" OF PLASTICS REPORTED BY SCHOENBORN AND WEAVER, AND RESULTS OF THE CONSTANT AIR TEMPERATURE METHOD OBTAINED AT THE NATIONAL BUREAU OF STANDARDS.

Plastics	Schoenborn and Weaver Method "Apparent Ignition Temperature," deg. Fahr.			Constant Temperature Method Ignition Temperature, deg. Fahr.	
	Min.	Max.	Dif.	With Igniter Flame	By Self Ignition
Phenolic paper laminate	449	685	236	644	968
Phenolic cotton fabric laminate	407	640	233	642	918
Phenolic asbestos paper laminate	410	830	420	720	932
Melamine, wood flour filler	355	650	295	...	...
Melamine, mineral filler	...	...	...	898	1130
Polystyrene, compression molded	320	495	175	653	910
Vinyl chloride, acetate, clear	265	309	44	680	1112
Cellulose acetate	184	320	136	580	842
Methyl methacrylate	295	...	...	574	860
Cellulose nitrate	...	...	...	291	291

The excessive irregularity and low values of the published results apparently result from the quite unusual significance attributed to the surface temperature in defining the ignition characteristics of a material as well as the difficulty of correct evaluation of this temperature at the instant of ignition by extrapolation of observed temperature at points within the specimen to a point on the bottom surface. This extrapolation is particularly difficult when, during the first stage of heating, the material melts, bubbles, blisters, or shrinks. The temperature at any point within the material or on the surface at an estimated point and at the instant of ignition has only relative significance in the rate of heating or self-heating process. This process is different at different points and at different times of observation, depending upon local temperature, access of oxygen for reaction with the material, concentration of products of oxidation, decomposition or distillation, thermal conductivity, and density of material, and other variable factors. Precise determination of the "true" temperature at the instant of ignition, even in uniformly reacting gas-air mixtures, is very difficult because of the high rate of temperature rise and the uncertainty in location of the actual ignition center. It is very difficult to make a determination by means of extrapolation from temperatures within a nonuniformly heated plastic material. For this reason, considerable variations in the derived results can scarcely be avoided and, accordingly, this temperature has generally been excluded in considerations of the ignition characteristics of materials.

Special attention is given to the surface temperature at which "volatile substances and pyrolytic decomposition products" are developed at a sufficient rate to be ignited by the igniter flame. In this instance, some important factors which have a dominant effect on the ignition or nonignition state of material were omitted. According to the fundamental theory of ignition, solids as well as liquids or their decomposition products are usually reduced to the vaporous or gaseous state of the material before ignition is accomplished. Therefore, the presence of a sufficient amount of air or oxygen is essential for the normal development of the ignition reaction of all combustible materials except those which contain sufficient oxygen, such as cellulose nitrate. The convection currents in the ignition apparatus described herein were small, and contamination of the air, at times, might have been appreciable. In many early types of ignition equipment, including the Krupp apparatus,[3] a controllable flow of air was supplied through coils of copper tubing placed inside of the furnace so that it was preheated when admitted at the bottom of the ignition chamber.

In the Bureau's new type ignition apparatus for solids and plastics, a refractory tube with thin walls is placed inside the furnace tube, and air is forced from above into the space between these tubes. Uniformly preheated air is supplied to the inner tube through the ports provided near its lower end. The maximum variations in the radial air temperature distribution within the inner tube is about 10 F. and in the axial direction about 25 F., in contrast with the corresponding variations of 140 F. and 230 F. shown in Fig. 2 of the paper. At the National Bureau of Standards, uniformity in the temperature of the air surrounding the specimens is usually with in 4 F. or less.

The adapter for holding specimens in the furnace used for the tests by Schoenborn and Weaver seems unsuited for the many types of plastics which change their physical state at temperatures below ignition. In order to hold the specimen in the same position in that furnace during these physical changes, the holding arrangement should be suitable for each particular type of

[3] *Automotive Industries*, Vol. 50, p. 6 (1924).

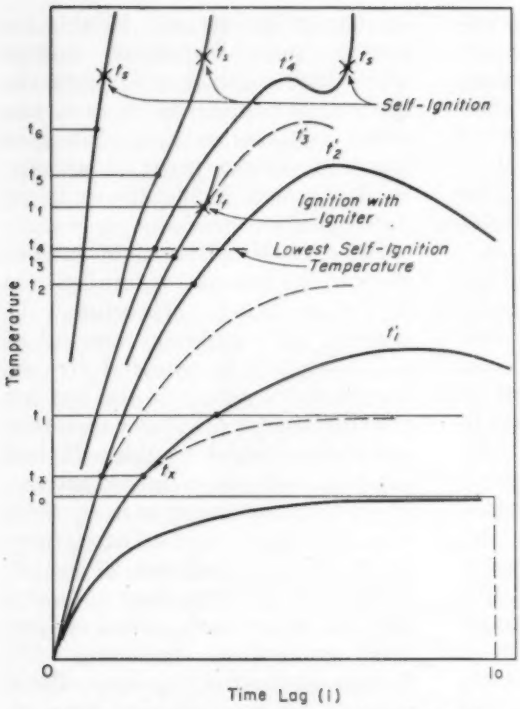

Fig. 1.—Constant-Air-Temperature Method.

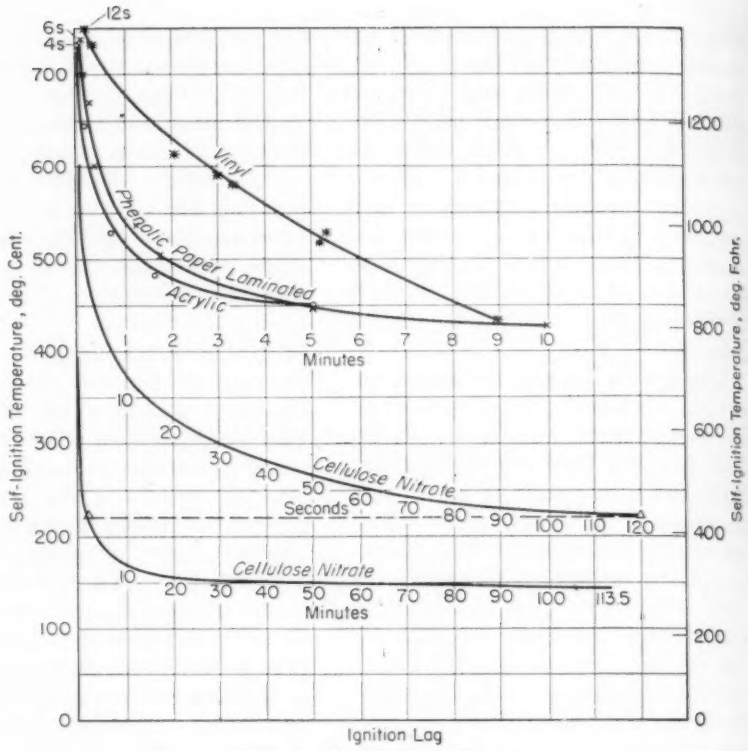

Fig. 2.—Ignition Lag Curves.

material. For example, materials remaining rigid during the test can be suspended on a wire; materials which flow, melt, or bubble can be held in a wire screen cup; materials which readily melt to a thin liquid state, like polymethyl methacrylate and polystyrene, or those which foam, like cellulose acetate, can be placed in a preheated porcelain crucible.

In order to observe the temperature of the air approaching the specimen, it is advisable to expose a bare thermocouple junction to the stream of air slightly below the specimen and at the same time to shield it from the specimen, which may radiate heat during an exothermic reaction. A small bare junction considerably increases the sensitivity of the temperature measurements and enables the furnace to be kept under better control. The position of the thermocouple within or on the specimen is unimportant, due to the relative significance of the temperature changes and the uncertainty of the location of the center of ignition. For simplicity it is sufficient to have the bare junction contact any surface of the specimen, or, in the case of sheet material, to place the junction between two sheets bound together with wire.

The accuracy and consistency of the determinations could have been improved if the authors had observed the temperature of the air around the specimen and assumed as most significant the temperature at which gases and vapors are developed at a sufficiently high rate to be ignited either by the igniter flame or by self-ignition.

The constant air temperature method was adopted by the National Bureau of Standards several years ago on the basis of experiments illustrated in the accompanying Fig. 1. If an incombustible material is subjected to heating at a constant temperature, t_0, the temperature of the material will be equalized with the temperature of the surrounding air after a certain time lag, l_0. This lag depends upon the mass, heat conductivity, specific heat, and the initial temperature difference between the air and the material. At relatively low air temperatures, similar behavior will also be observed with combustible materials. However, at a certain air temperature, t_1, higher than the incipient temperature of oxidation, t_x, the material begins to oxidize with the generation of heat, and the temperature of material from the point t_x will be increased faster than it would be in the normal process of heating without the oxidation. The temperature of the material will continue to increase above the initial temperature, t_1, until a maximum temperature, t'_1, is reached. This rise in temperature is often accompanied by development of vapor or gas, which in this stage may not be inflamed because of the low rate of development and dilution with air. At some other constant initial air temperature, t_2, the material may self-heat due to oxidation to some higher temperature, t'_2. However, after self-heating from initial air temperature, t_3, the concentration of combustible gases or vapors may be sufficient to be ignited by the igniter flame at instantaneous temperature, t_f, which is often below the maximum temperature, t'_2, of the previous case, at which temperature ignition did not occur. Moreover, in the absence of the igniter flame, self-heating may proceed to a maximum temperature, t'_3, without self-ignition. Because of this condition, regularly observed for many materials, the instantaneous temperature, t_f, has no important significance, even if this temperature could be determined accurately, because the surface temperature, as well as the rate of heat generation and rate of gas development, depends mainly upon the ini-

tial temperature and velocity of air passing around the specimen.

In many cases it was observed that the rate of the exothermic reaction at a temperature peak such as t'_4 is reduced by excessive contamination of the air, by cooling from too high rate of air flow, or by endothermic reactions. After proper adjustment of the air flow, the oxidation reaction from the point t'_4 may be accelerated to self-ignition of gases at another observed temperature, t_s. This temperature, together with t_f, also has no important significance in relation to the ignition characteristics because it depends upon the optimum rate of air flow and initial air temperature, t_4. Therefore, the lowest initial air temperature, which eventually leads to observable ignition with the optimum rate of air flow, is considered as a major ignition characteristic and with absence of an ignition source is called the self-ignition temperature of the material.

At higher initial temperatures, t_5, t_6, self-ignition occurs more readily and the ignition lag rapidly decreases with increase in initial temperature, the relation between lag and temperature being approximately logarithmic. The lowest self-ignition temperature may occur with ignition lags from a few minutes to an hour or more. With higher initial temperatures, the ignition lag may be only a few seconds or even a fraction of a second. Different types of relationship between the self-ignition temperature (initial air temperature) and the time lag are observed for different materials as shown in Fig. 2 of this discussion. According to these relationships, the ignition lags observed at the same air temperature for different materials are not found proportional nor well correlated with the lowest self-ignition temperatures of the corresponding materials. The ignition lag also varies with the mass as well as the physical and thermo-chemical properties of the material, and hence alone does not give a significant evaluation of ignition characteristics as Schoenborn and Weaver anticipated.

The constant-air-temperature method for the determination of the ignition property of materials is based upon the ignition from the self-heating of the material initiated under the lowest constant temperature of air passing around the specimens with optimum velocity. This method gives consistent results, reproducible with a good degree of accuracy. It is advantageous in comparison with other methods because of the simplicity and the precision in the determination of effective air temperature, which temperature can be sustained constant for any given period of time.

It would be of interest to many if Schoenborn and Weaver, were to try this method in comparison with their constant-furnace-temperature method in which furnace temperatures are above the ignition temperatures of the materials.

MESSRS. E. M. SCHOENBORN AND D. S. WEAVER, JR. (*authors' closure by letter*).—The authors are glad to have the detailed comments of Mr. Setchkin and to know of the work which the Bureau is carrying out on this problem. It is evident that there is more than one approach to the general problem of determining the ignition temperatures of plastic materials, and the authors have attempted to suggest one means whereby such data might be obtained.

Measurement of the temperature of the air around the specimen was early considered as a possible means for arriving at the ignition characteristics of the material but was abandoned when heat-transfer considerations indicated that at the low air velocities which would normally prevail the temperature gradient in the air film adjacent to the surface would be large. In other words, the temperature of the surface would approach that of the heating air only after a long period of time. Setchkin's method correctly implies that the temperature at a point near the specimen surface will depend, among others, on the air velocity past the surface. The small deviations encountered and the reproducibility of the results obtained, however, do not in themselves indicate that a true surface temperature is evaluated.

An improper extrapolation and use of too few data points probably account for the low value of apparent ignition temperature for cellulose acetate referred to. As pointed out in the paper, extrapolation of the temperatures observed within a specimen, especially for those materials which deform or otherwise undergo physical and chemical change on heating, poses a difficulty. It was for this reason that the term "apparent" ignition temperature was adopted as a measure of the flammability characteristics of a material. The constant-air-temperature method of course obviates the necessity of utilizing specimens of any particular shape and size and serves to overcome the difficulties due to flowing, melting, bubbling, etc. In this respect the method possesses distinct advantages. Furthermore, if the optimum air velocity were the same for all materials or could be standardized so that the temperature at a fixed point in the air stream could be taken to characterize ignition, the method would probably be simpler and easier to employ—at least as a means for comparing the relative ignition temperature of various materials.

The Use of the Rossi-Peakes Flow Tester in Measuring the Apparent Viscosity of Plastics at Temperatures from 115 to 175 C

By F. E. Piech[1] and W. E. Gloor[2]

THE Rossi-Peakes flow tester (8)[3] (also known as the Bakelite-Olsen tester) has come to be recognized as the standard apparatus for measuring flow properties of thermoplastic materials. Specified in Tentative Method of Test for Measuring the Flow Properties of Thermoplastic Molding Materials (D569–44 T),[4] the apparatus is installed in nearly 50 laboratories, according to a recent survey of Committee D-20 on Plastics. Since the apparatus is similar in construction to a Bingham and Murray Plastometer (1), an effort was made to use it as such to measure the viscosity of plastics in the region of their flow temperatures.

Considering the procedure of Method D 569, it is clear that the duration of the test embraces the time needed to heat the specimen sufficiently to allow it to flow under pressure, plus that needed for the flow to occur. If the test were conducted with a fully heated specimen, the apparatus would operate as a plastometer under conditions of constant temperature, and the flow should be similar to that found with a Bingham and Murray plastometer (1). This report describes the results obtained when the instrument is operated in this manner.

Equipment

A Rossi-Peakes flow tester as specified in Method D 569, with steam-heated cone receptacle and plunger, was used. Line steam pressure was available up to 165 psi., and a trap was used to clear the condensate. This was a Bishop-Babcock universal trap which discharged without change of orifice at all steam pressures. A calibrated thermometer measured instrument temperature, and time was recorded on the Esterline-Angus recorder provided with the instrument.

Procedure

Temperature was controlled by varying the steam pressure to attain the desired thermometer reading. A curve, resulting from several years' experience, enabled the operator to select the pressure needed for a given temperature. If the temperature was low, due to wet steam or scale in the line, the steam supply was purged until a proper reading, conforming to experience, was attained.

Cylinders of dry molding powder $\frac{3}{8}$ by $\frac{3}{8}$ in. were pelleted to about 0.7-g. weight and placed in a desiccator charged with fresh Dehydrite. The desired weight and temperature were selected, the machine brought to and held at this temperature for at least 2 min.; then the sample was placed on the ram and brought into contact with the follower rod in the cone, which was held in place by the lock bar. Exactly 3 min. after contact, the lock bar was extracted and flow commenced. The time required for a specimen to flow various distances, (usually within 10 min). was noted as flow proceeded. It was customary to make a number of runs at one temperature, varying weights as needed. On each loading for each formula at least two measurements were made at each temperature.

When changing material in the cylinder, a half dozen or more clean-out pellets were run through the capillary to attain constant flow conditions. It will be noted that the flow tester was operated by preheating the text pellet for 3 min. under the working pressure and temperature before releasing the flow. From average data on the heat transfer coefficient of cellulosie plastics, calculated for spheres or infinite cylinders by the method of Gurney and Lurie (7), it appeared that the pellet should have attained a temperature at its center within 5 per cent of the temperature differential (operating temperature minus pellet temperature) within 1 min.

Materials Tested

Large-scale laboratory batches of molding powder, made by methods described elsewhere, (6), formed the basis of most of the tests. Some samples of commercial molding powders were also studied. The cellulose acetate and ethyl cellulose plastics studied covered a rather wide range of formulations (see Table I) of different flow classification.

TABLE I.—FORMULAS OF PLASTICS TESTED.

	Formula A	Formula B	Formula C	Formula D	Formula E	Formula F
Cellulose acetate[a]	70	74	...	...	75	...
Ethyl cellulose[b]	...	...	86	90	...	90
Dimethyl phthalate	10	6.5	...	...	...	...
Diethyl phthalate	20	19.5	...	...	...	...
Dibutyl phthalate	...	...	7	5	...	...
Diamylnaphthalene	...	...	7	5	...	...
Triacetin	...	...	...	...	25	...
Methyl cellosolve stearate	...	...	...	...	...	10
Diphenylamine	...	...	0.5	0.5	...	0.25
Flow temperature, deg. Cent.	135	144	141	160	167	148

[a] Analysis: 53 to 53.5 per cent acetic acid, 40 sec. viscosity (20 per cent concentration in 9: 1 acetone ethanol).

[b] Analysis: 44.5 to 45.5 per cent ethoxyl, 100 cp. viscosity (5 per cent concentration in 8: 2 toluene ethanol).

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] Parlin Plant, Hercules Powder Co., Parlin, N. J.

[2] New Product Development Hercules Powder Co., Wilmington, Del.

[3] The boldface numbers in parentheses refer to the references appended to this paper.

[4] 1946 Book of A.S.T.M. Standards, Part III-B, p. 863.

Their flow properties are shown in Table II.

Cellulose acetate and ethyl cellulose plastics were chosen for this study, since the flow properties of these materials are known to be somewhat different.

Results Obtained

Observations on flow of the first four plastic formulations listed as A, B, C, and D in Table I are reported in Table II and plotted in Figs. 1 and 2. Because of the wide ranges of temperature (115 to 175 C.) and pressure (100 to 3000 psi.) studied, data for complete flow curves could not be obtained in most cases.

Flow data for materials E and F (see formulas, Table I) were measured at their flow temperatures, being measured both immediately after loading as specified in Method D 569 procedure, and after 3-min. preheating under load. Special measurements were made on the samples which in these tests had flowed the longest distance in order to determine the extent of delayed elastic retraction. These special tests were made by heating the flow pellets, stem side down, in an oven at the flow temperature, for 24 hr. Flow curves are shown in Figs. 3 and 4. Data for retraction and calculated apparent viscosity appear in Table III.

Interpretation of Results

As noted by Scott-Blair, (6), the flow of a truly viscous liquid through a capillary of the type used (Fig. 5) should follow the relation:

$$N = \frac{t}{L^2} \times \frac{PR^2}{4}$$

where:

N = viscosity in poises,
t = time in seconds to flow distance L in centimeters,
P = pressure, dynes per square centimeter, and
R = radius of the capillary in centimeters.

Foote (5) has applied this relation to the flow of polystyrene through capillaries of an apparatus similar to that described by Burns (3).

From the dimensions of the flow tester, the kinetic energy and end effect corrections would not affect the values of apparent viscosities calculated using this equation by

TABLE II.—BASIC FLOW DATA ON TYPICAL PLASTICS.

Formula	Temperature, deg. Cent.	Pressure, psi.	Flow, in.	Time to Flow, sec.	Apparent Viscosity, poises
A	175	600	1	1	4.0×10^4
			1.3	2	4.8×10^4
		300	1	5	1.0×10^5
			1.3	13	1.6×10^5
		100	0.3	7	5.2×10^5
			0.6	32	5.9×10^5
			1.0	145	9.7×10^5
			1.3	355	1.4×10^6
		600	0.3	2	9.0×10^5
			0.6	17	1.9×10^6
			1.0	53	2.1×10^6
			1.3	95	2.3×10^6
	155	300	0.3	8	1.8×10^6
			0.6	32	1.9×10^6
			1.0	92	1.9×10^6
			1.3	165	2.0×10^6
		100	0.3	71	5.3×10^6
			0.6	320	6.0×10^6
			0.78	600	6.6×10^6
		3000	0.6	5	2.8×10^6
			1.0	20	4.0×10^6
			1.3	40	4.8×10^6
	135	600	0.3	190	8.5×10^7
			0.38	600	1.7×10^8
		300	0.19	600	3.3×10^8
		100	0.04	600	2.5×10^8
		3000	0.30	144	3.2×10^6
	115		0.44	600	6.3×10^6
		600	0.07	600	4.9×10^7
		300	0.6	3	1.7×10^5
			1.0	16	3.2×10^5
			1.3	36	4.3×10^5
	175	100	0.3	25	1.9×10^6
			0.6	120	2.2×10^6
			1.0	360	2.4×10^6
			1.22	600	2.7×10^6
		3000	0.6	0.25	1.4×10^4
			1.0	2	4.0×10^5
			1.3	5	6.0×10^5
		1500	0.3	2	2.2×10^6
			0.6	7	2.0×10^6
			0.8	15	2.3×10^6
B	155		1.0	27	2.7×10^6
			1.3	62	3.7×10^6
		600	0.3	16	7.2×10^6
			0.6	125	1.4×10^7
			0.8	285	1.8×10^7
			1.0	540	2.2×10^7
		300	0.2	46	2.3×10^7
			0.3	125	3.8×10^7
			0.4	255	3.4×10^7
	155		0.53	600	4.3×10^7
		200	0.1	13	4.4×10^6
			0.2	85	1.4×10^7
			0.3	370	3.1×10^7
		100	0.24	600	7.0×10^7
		600	1.0	3	1.2×10^5
			1.3	13	3.1×10^5
		300	0.6	10	5.6×10^5
	175		1.0	85	1.7×10^6
			1.3	323	4.0×10^6
		100	0.23	600	7.6×10^7
		600	0.3	1	4.5×10^5
			0.6	7	7.9×10^5
			1.0	173	7.0×10^6
	155		1.2	600	1.7×10^7
C		300	0.3	40	9.0×10^5
			0.51	600	4.6×10^7
		100	0.08	600	6.3×10^8
		3000	1.0	3	6.1×10^5
			1.3	9	1.1×10^6
	135	600	0.3	82	3.7×10^7
			0.4	600	1.4×10^8
		300	0.14	600	6.2×10^8
		3000	0.30	36	8.1×10^7
	115		0.55	600	4.0×10^8
		600	0.03	600	2.7×10^{10}
		600	0.6	2	2.2×10^5
			1.0	13	5.2×10^5
			1.3	75	1.8×10^6
	175	300	0.3	3	6.7×10^5
			0.6	60	3.4×10^6
			0.93	600	1.4×10^7
		100	0.11	600	3.3×10^8
		3000	1.0	1	2.0×10^5
			1.3	2	2.4×10^5
		1500	0.8	1	1.6×10^5
			1.0	2.5	2.5×10^5
			1.3	8	4.8×10^5
		600	0.3	2	9.0×10^5
			0.6	25	2.8×10^6
	155		0.8	260	1.6×10^7
D			1.0	775	3.1×10^7
		300	0.1	3	6.1×10^6
			0.2	25	2.5×10^7
			0.3	185	4.2×10^7
			0.37	600	8.8×10^7
		200	0.1	13	4.4×10^6
			0.2	85	1.4×10^7
			0.3	370	3.1×10^7
		100	0.05	600	1.6×10^9
		3000	0.3	2	4.4×10^5
			0.6	17	9.6×10^5
	135		1.0	134	2.7×10^7
			1.24	600	7.9×10^7
		600	0.19	600	6.7×10^8
		300	0.09	600	1.5×10^{10}
		3000	0.18	600	3.7×10^9
	115	600	0.02	600	6.1×10^{10}

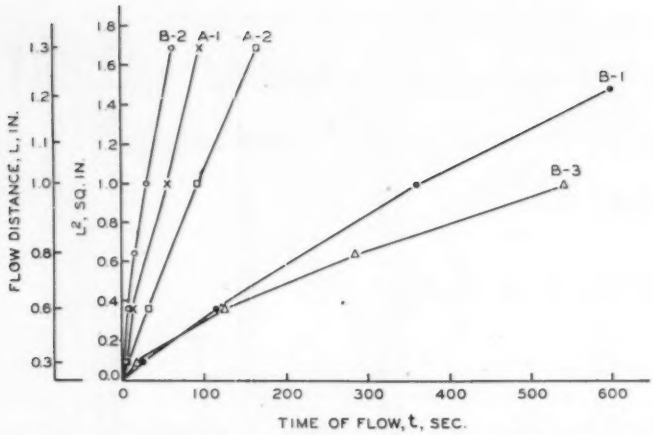

Fig. 1.—Curves Showing L^2 *versus* t Relation for Cellulose Acetate Plastics.

Material A: A-1 at 155 C. and 600 psi.
A-2 at 155 C. and 300 psi.
Material B: B-1 at 175 C. and 100 psi.
B-2 at 155 C. and 1500 psi.
B-3 at 155 C. and 600 psi.

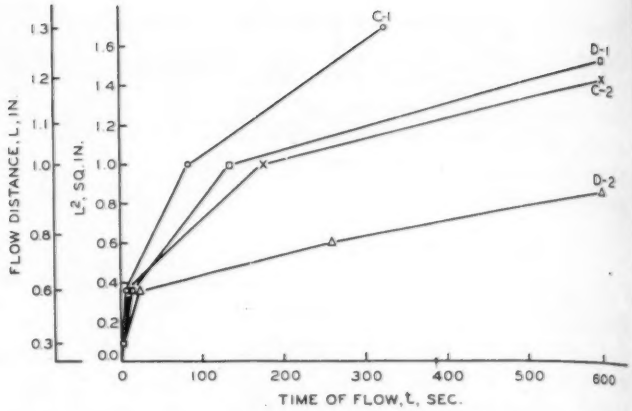

Fig. 2.—Curves showing L^2 *versus* t Relation for Ethyl Cellulose Plastics.

Material C: C-1 at 175 C. and 300 psi.
C-2 at 155 C. and 600 psi.
Material D: D-1 at 135 C. and 3000 psi.
D-2 at 155 C. and 600 psi.

more than 5 per cent, which is of the same order of magnitude as the reproducibility of the measurements. Since there is an unknown pressure drop between the face of the ram and the entrance to the capillary, the apparent viscosities so calculated are probably maximum values.

If the equation for viscosity shown above holds strictly, measurements upon a given material at a given temperature should show that:

1. For constant time t and distance of flow L, the pressure P required should be inversely proportional to the square of the radius R of the capillary used; that is, P should vary as $1/R^2$. Since the flow tester has only one fixed capillary radius, this relation could not be tested.

2. For constant capillary radius R and distance of flow L, flow time t should vary as the reciprocal of pressure $1/P$. This relation can be tested in the flow tester.

3. For constant pressure P and distance of flow L, the time of flow should vary as $1/R^2$. For the reason given in item 1, this could not be checked in the flow tester.

4. For constant pressure P and time of flow t, the flow distance L should be proportional to the capillary radius R. While this cannot be tested in the flow tester, data kindly supplied us by Robert Burns[5] (see Fig. 6) using his capillary flow tester are available.

5. For constant capillary radius R and time of flow t, the square of the distance flowed L^2 should be proportional to the pressure P. This relation can be examined in the flow tester.

6. For constant capillary radius R and pressure P, the time of flow t should be proportional to the square of the distance flowed L^2. This relation can also be tested in the flow tester.

[5] R. Burns, private communication.

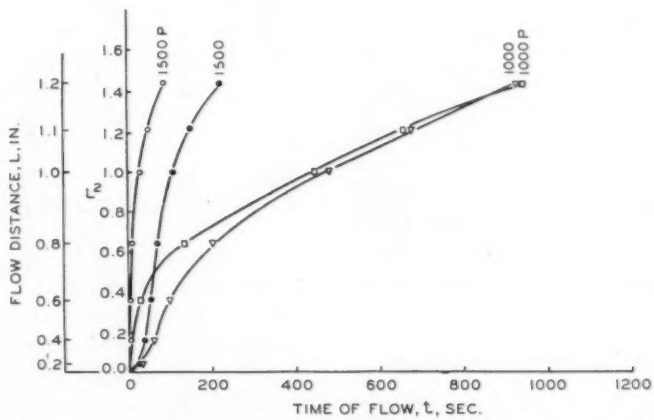

Fig. 3.—Curves showing L^2 *versus* t Relation for Cellulose Acetate Plastic E at Its Flow Temperature (167 C.).

Numerals denote pressure of test in psi.
Numerals followed by P denote data obtained by preheating plastic for 3 min. at the flow temperature and pressure shown, before flow begins.

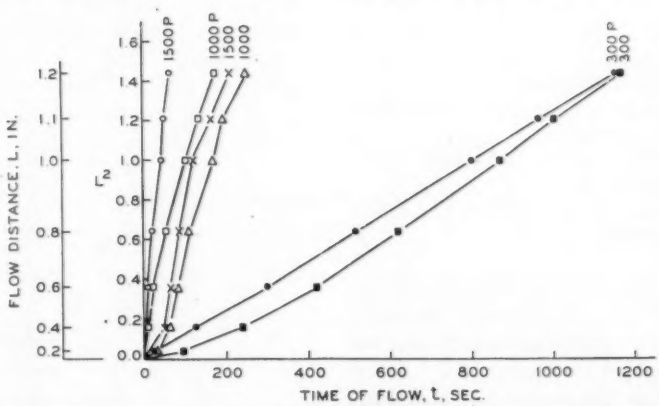

Fig. 4.—Curves Showing L^2 *versus* t Relation for Ethyl Cellulose Plastic F at Its Flow Temperature (148 C.).

Numerals denote pressure of test in psi.
Numerals followed by P denote data obtained by preheating plastic for 3 min. at the flow temperature and pressure shown, before flow begins.

TABLE III.—FLOW OF MATERIALS UNDER VARIED CONDITIONS OF PREHEATING AT FLOW TEMPERATURE.

Material	Pressure, psi.	Not Preheated		Preheated 3 min., at Flow Temperature	
		Flow, in.	Time to Flow, sec.	Time to Flow, sec.	Apparent Viscosity, poises
E (Flow Temperature, 167 C.)	1500	0.2	29	1	2.5×10^6
		0.4	46	2	1.3×10^6
		0.6	62	5	1.4×10^6
		0.8	85	14	2.2×10^6
		1.0	116	33	3.3×10^6
		1.1	133	48	4.0×10^6
		1.2	159	67	4.7×10^6
Retracted Length, in.		0.95		0.88	
Retraction, per cent		21		26	
E	1000	0.2	32	1	1.7×10^6
		0.4	53	6	2.4×10^6
		0.6	78	21	3.9×10^6
		0.8	108	52	5.6×10^6
		1.0	170	104	6.9×10^6
		1.1	195	139	7.7×10^6
		1.2	244	180	8.4×10^6
Retracted Length, in.		1.00		1.00	
Retraction, per cent		16		16	
E	300	0.2	95	27	1.35×10^7
		0.4	240	130	1.66×10^7
		0.6	420	300	1.68×10^7
		0.8	620	515	1.62×10^7
		1.0	870	800	1.61×10^7
		1.1	1005	965	1.61×10^7
		1.2	1170	1155	1.61×10^7
Retracted Length, in.		1.11		1.13	
Retraction, per cent		7		6	
F (Flow Temperature, 148 C.)	1500	0.2	24	1	2.52×10^6
		0.4	40	2	1.26×10^6
		0.6	53	3	0.84×10^6
		0.8	71	11	1.73×10^6
		1.0	106	28	2.82×10^6
		1.1	146	49	4.07×10^6
		1.2	219	86	6.01×10^6
Retracted Length, in.		1.08		1.09	
Retraction, per cent		10		9	
F	1000	0.2	30	1	1.68×10^6
		0.4	60	5	2.09×10^6
		0.6	98	29	5.42×10^6
		0.8	198	139	1.46×10^7
		1.0	477	443	2.98×10^7
		1.1	676	653	3.63×10^7
		1.2	925	936	4.37×10^7
Retracted Length, in.		1.12		1.14	
Retraction, per cent		7		5	

All these points except items 1 and 3 can thus be considered with the aid of the data in Table II and Fig. 6. At the same flow distance in the capillary, variation of pressure on the sample led to a flow time much different from that expected from the reasoning of item 2. In general, both cellulose acetate and ethyl cellulose show equally wide deviations from the ideal behavior. On item 4, data from the Burns flow tester (Fig. 6) indicate that at constant temperature, pressure, and time of flow, the distance flowed by the cellulose acetate plastics is exactly proportional to the radius of the capillary in which flow took place; they show nearly the expected proportional relationships with the ethyl cellulose plastics. The deviation of the experimental points from the theoretical straight line for the latter material may be of some significance. On item 5, comparison of the square of the flows L^2 for the same flow time t, at various pressures in the fixed capillary radius of the flow tester, shows that flows do not follow the expected variation with pressure. Wiley (11), in fact, shows that L varies linearly with P. On item 6, Scott-Blair's test for viscous flow, comparing L^2 with time of flow t at a fixed pressure and capillary radius, it is seen that with cellulose acetates the law is obeyed quite well, while ethyl cellulose shows marked deviations. This is an outstanding difference between the two types of cellulose plastic. The effect is illustrated by the curves of Figs. 1 and 3, plotted for cellulose acetate, as compared with those of Figs. 2 and 4, plotted for ethyl cellulose. It is also illustrated by the relative constancy (only five-fold variation) of apparent viscosity of cellulose acetate samples at any one pressure seen in Tables II and III, as compared with wider variations (10 to 30-fold) for ethyl cellulose.

The apparent viscosity of ethyl cellulose plastics will vary as much as 10,000-fold, over the pressure range 100 to 3000 psi.

The data in Tables II and III indicate that structural viscosity is probably the governing factor in the change of apparent viscosity with pressure which was observed with preheated samples. A drop in viscosity as shearing stress increases is expected with materials of this sort, since the nature of the flow changes from that found in the region where structural viscosity governs to that found in the region where laminar flow begins, following Ostwald's conception of the phenomenon of structural viscosity.

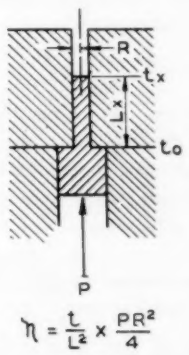

Fig. 5.—The Flow Test Capillary Considered as a Plastometer.

R = capillary radius (0.0625 in.),
P = pressure (variable),
t_o = denotes position of flow stream at start of test, and
t_x = position of flow stream at time t_x in seconds during which it has flowed the distance L_x in inches.

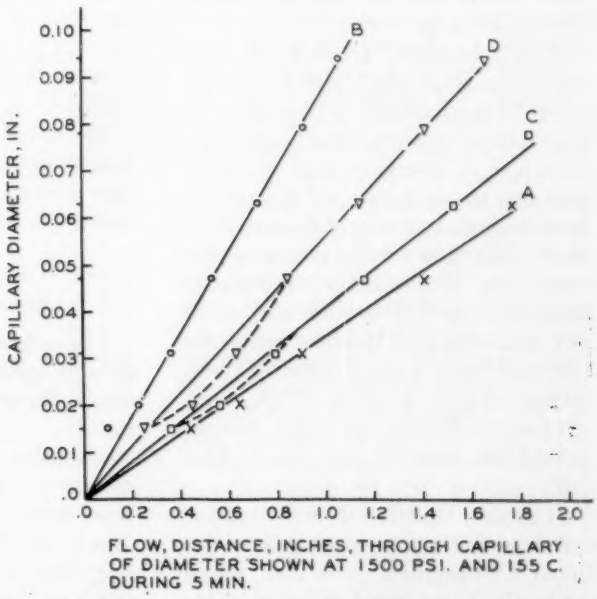

Fig. 6.—Variation in Flow of Cellulose Plastics with Capillary Diameter.

Measured in Burns Flow Tester (3).
Letters correspond to plastics in Table I.
Flows measured at 155 C. and 1500 psi. after 5 min. flow time.

This conception is also borne out if the flow data are plotted by comparing rates of shear with shearing stress. Curves are obtained which start from the origin and bend concavely upward (plotting rate of shear as ordinate against shearing stress as abscissa), and then become nearly straight lines. At a limiting rate of shear the curves lose regularity, probably because the speed of flow is too fast for the instrument. These "mobility" curves are nearly straight lines at flow rates of from 0.01 to 0.20 in. per sec.

An effort was made to compare the apparent viscosity of the plastics with the maximum shear rate existing in the flow capillary, using the method suggested by Barr (2). Following his suggestion, maximum shear rate S may be calculated from the relation:

$$S = \frac{4L}{rt}$$

where:

L = distance of flow in capillary in centimeters,
r = capillary radius in centimeters, and
t = time of flow in seconds.

If one plots apparent viscosity as ordinate against maximum shear rate as abscissa, curves are obtained which approach a minimum value in passing from low to high shear rates but which again become irregular when calculated from data taken at flow speeds in the capillary faster than 0.20 in. per sec.

The materials E and F were tested, as shown in Table III, in an effort to shed a little light on Foote's speculation concerning whether this variation of viscosity with pressure was due to an impressed elastic deformation or to the evolution of heat during the flow of the plastic in the capillary. These flows were measured upon materials with and without preheating at the flow temperature and retraction of the flow piece measured after heating 24 hr. in an oven at the flow temperature, as suggested by Spurlin and co-workers (10).

It is seen that the flow curves for cellulose acetate plastics follow the linear L^2/t relation quite well, while again those for ethyl cellulose vary considerably from this law, measured by both methods of heating. Further, in those tests made without preheat, in no case did it seem that more than 40 sec. were consumed for the materials flowing under high pressure (1000 to 1500 psi.) to attain the uniform heat, thus justifying one of the assumptions upon which this work was based. The data on retraction indicate that for the cellulose acetate plastics as much as 50 per cent of the pressure sensitivity of viscosity may be attributed to this elastic deformation (Table IV). Substantially less retraction was observed for ethyl cellulose plastics. The amount of elastic retraction was practically the same whether the samples tested were preheated or not. With the few tests shown here, it appears also that the amount of elastic retraction is greater, the higher the pressure of flow. This effect also seems independent of the conditions of initial heating. The fact that the ethyl cellulose plastics flowed less readily as the distance of flow increased (cellulose acetate showing also a slight tendency of this kind) argues against the hypothesis that heat is generated during the flow of the plastic through a capillary. A higher temperature so generated would call for more flow and hence would lower apparent viscosity as flow continued, while in fact the reverse was usually observed.

TABLE IV.—COMPARISON OF APPARENT VISCOSITIES OF CELLULOSE ACETATE PLASTIC SAMPLE E WITH AND WITHOUT CORRECTION FOR ELASTIC DEFORMATION

Samples run at Flow Temperature (167 C.) and 1500 psi. with 3 min. preheat.

	Apparent Viscosity, Calculated from Time to Flow 1 in.		Apparent Viscosity, Calculated from Corrected Time to Flow 1 in.	
Pressure, psi.	Time, sec.	Apparent Viscosity, poises	Time, sec.	Apparent Viscosity, poises
300.....	800	1.67×10^7	958	1.93×10^7
1000.....	102.5	6.89×10^6	180	1.21×10^7
1500.....	32.5	3.27×10^6	87	8.77×10^6
Ratio: $\frac{\text{Apparent Viscosity at 300 psi.}}{\text{Apparent Viscosity at 1500 psi.}}$	5.1		2.2	

Apparent Viscosity at the Flow Temperature

The correction of the maximum flow of cellulose acetate plastics for elastic deformation thus permits one to calculate a viscosity from the data on samples preheated for 3 min., as shown in Table IV. This calculated value is somewhat lower than that given by Dienes in compression flow tests (4). The values obtained, however, are fairly consistent with the viscosities observed by Wiley (11) on materials of similar flow temperature as that of sample E.

It is of interest to calculate the approximate viscosity of a plastic at the flow temperature. It appears that, for cellulose acetate plastics, one would be justified in assuming,

1. That 20 per cent of the flow is due to elastic deformation.
2. That the first 40 sec. of flow time are occupied largely in heating up the plastic, with little flow taking place. Hence, in the equation

$$N = \frac{t}{L^2} \times \frac{PR^2}{4}$$

using

$t = 120 - 40 = 80$ sec.
$L = 2.54 \times 0.8 = 2.03$ cm.
$P = 1500 \times 6.89 \times 10^4 = 1.035 \times 10^8$ dynes per sq. cm.
$R = 0.1588$ cm.; $R^2 = 252 \times 10^{-4}$ sq. cm.

$$N = \frac{80 \times 1.035 \times 10^8 \times 252 \times 10^{-4}}{4.12 \times 4} = 1.27 \times 10^7 \text{ poises}$$

It should be noted that this value is within 50 per cent of that obtained using the corrected value calculated in Table IV. Considering the arbitrary nature of the time correction, the slight variations of temperature of the capillary, and the unknown pressure drop in the molten plastic from the ram face to the entrance of the capillary, this can be considered a check. Hence for practical purposes one can consider the flow temperature of a plastic cellulose acetate as the temperature at which the material has a viscosity of about 10^7 poises at a pressure of 1500 psi.

Summary

The Rossi-Peakes flow tester called for by Tentative Method D 569 was operated as a plastometer by preheating the flow pellet in the heating cylinder for 3 min. before releasing flow. Apparent viscosities were calculated for ethyl cellulose and cellulose acetate plastics over a

range of temperatures and pressures. Both plastics are pressure-sensitive, and in addition, ethyl cellulose does not follow the normal linear relation between the square of the flow distance and time of flow.

With cellulose acetate plastics about half of this pressure sensitivity of viscosity can be explained by delayed elastic displacement of the plastic during test; ethyl cellulose plastic showed less elastic deformation, but somewhat more pressure sensitivity.

In the A.S.T.M. flow test (D 569), about 40 of the 120-sec. test time is spent in heating the plastic pellet to the test temperature, and about 20 per cent of the observed flow in cellulose acetate is due to elastic deformation of the sample. With these corrections, the apparent viscosity of a cellulose acetate plastic at the A.S.T.M. flow temperature is about 10^7 poises.

References

(1) E. C. Bingham and H. A. Murray, "A New Combined Viscometer and Plastometer," *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part II, p. 655 (1923).

(2) G. Barr, "A Monograph on Viscometry," Humphrey Milford, London, p. 275 (1931).

(3) R. Burns, "Measuring the Viscosity of Molding Compounds," *Proceedings*, Am. Soc. Testing Mats., Vol. 40, p. 1283 (1940).

(4) G. J. Dienes and H. F. Klemm, "Theory and Application of the Parallel Plate Plastometer," *Journal Applied Physics*, Vol. 17, p. 458 (1946).

(5) N. M. Foote, "Thermoplastic Flow of Polystyrene," *Industrial and Engineering Chemistry*, Vol. 36, p. 244 (1944).

(6) W. E. Gloor, "Low Temperature Impact Strength of Cellulosic Plastics," *Industrial and Engineering Chemistry*, Vol. 39, p. 1125 (1947).

(7) H. P. Gurney and J. Lurie, "Charts for Estimating Temperature Distributions in Heating or Cooling Solid Shapes," *Industrial and Engineering Chemistry*, Vol. 15, p. 1170 (1923).

(8) G. L. Peakes, "Measuring Plasticity of Hot Molding Compounds. Description of the Flow Tester," *Plastic Products*, Vol. 10, pp. 53–57, 93–98, 132–135 (1934).

(9) G. W. Scott-Blair, *Industrial Rheology*, Blakiston, Philadelphia, Pa., p. 54 (1938).

(10) H. M. Spurlin, A. F. Martin, and H. G. Tennent, "Characterization of Cellulose Derivatives by Solution Properties, Plasticizers as Solvents," *Journal Polymer Science*, Vol. 1, pp. 63–74 (1946).

(11) F. E. Wiley, "Working Range Flow Properties of Thermoplastics," *Industrial and Engineering Chemistry*, Vol. 33, p. 1377 (1941).

Plastics as Optical Materials[1]

By H. R. Moulton[2]

With the first appearance of clear, transparent, inorganic plastics or resins, there simultaneously appeared an intense interest in their use as optical materials. The recent effective and, in some cases, spectacular employment of such products has perhaps created the impression that only now can plastics be used successfully as optical elements, or that only now are plastics and techniques available for such use.

A survey of the patent literature shows that, since the early days of celluloid, inventors have visualized the use of plastics for optical elements, and each new, clear, transparent, synthetic resin, whether thermosetting or thermoplastic, has been claimed as a glass substitute. Some of the materials proposed are: cellulose nitrate and other cellulose esters and ethers, esters of acrylic and methacrylic acid, polystyrene and its relatives, allyl compounds, aldehyde-urea resins and their relatives, phenolic resins and their relatives, in addition to copolymers of various types. In fact, even certain proteins and their compounds have been considered.

Some of the advantages claimed for the use of such materials for lenses and optical elements are lightness, reduced fragility, and less involved methods of processing the materials to produce the finished articles. To one who has seen the facility and speed with which injection-molded articles can be produced and who compares this process with the conventional processes of fabricating glass lenses, the advantages of making lenses from plastics seem overwhelming. The difficulties encountered in molding lenses are less obvious.

Optical Requirements

For satisfactory use, the material used for a lens must be optically homogeneous. That is, a ray of light must not take a path through the lens which differs from the path computed by the designer of the lens. Portions of the lens having higher or lower index of refraction cause the path of the ray to be deviated more or less than desired and as a result the image-forming or image-modifying properties of the lens are impaired. The amount of variation in index that can be tolerated is amazingly small. For spectacle lenses, a variation of one in the fourth decimal place cannot be tolerated. For a large precision roof prism, a variation of one in the sixth decimal place is intolerable.

It is not easy to attain these requirements in glass. Stringent inspection of the raw glass produced by melting is necessary, and great care must be taken in all the subsequent processing to avoid introducing irregularities of index or increasing any irregularities which were originally present but tolerable. In molding the glass to approximate shape, as is done in making spectacle lenses and some other types of lenses, great care must be taken to avoid irregular flow of the soft glass. In molding plastics, especially by injection or transfer methods, it is generally the case that extreme irregularity of flow occurs with all the attendant irregularity of index. While certain lenses of very slight focal power may be injection molded, the production by this method of lenses of real optical usefulness has not been practical thus far.

Uniformity of index depends not only upon uniformity of composition. It also depends upon the absence of strain. While this is serious in glass, it can be taken care of to a satisfactory degree in the preliminary operations, before the optical surfaces are produced. In molding plastic optical elements, however, the strain, and generally it is irregular strain, is produced during the production of the optical surfaces. Thus a lens, produced by injection molding a thermoplastic, might have surfaces of adequate accuracy and yet be completely useless optically.

Methods

To avoid this type of difficulty, considerable work has been done in the molding of optical elements of plastics by starting with cast sheets of good homogeneity and forming or pressing

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[2] Assistant Director of Research, American Optical Co., Southbridge, Mass.

them to the desired curvatures between highly polished mold faces. (Incidentally, the preparation of sufficiently smooth and accurate mold faces is not simple.) The resulting element (a lens, for example) is homogeneous from a chemical or molecular weight standpoint, but we still have the problem of strain to contend with because we have caused the material to flow under stress. But within certain limits of curvature, fairly good lenses have been made by this method. It lends itself particularly well to substantially flat lenses having long radii of curvature or lenses of irregular nature, very time-consuming and difficult to make in glass. But for steep curves and for thick lenses it has its drawbacks, for air may be trapped and excessive flow of the plastic is necessary. A preliminary mechanical shaping operation has sometimes been used to overcome these troubles.

Many of the most recently developed resins, such as those of the allyl class, have very useful properties but do not lend themselves to molding or forming. The casting technique, in which partially polymerized material is poured between accurate mold faces and the polymerization completed, is necessary. It has been found possible to follow the same procedure with many of the older types of resinous materials, notably with the methacrylates and with styrene. The big difficulty with this process is shrinkage, but by a variety of manipulations—partly mechanical and partly chemical—the shrinkage problem can be overcome, at least in part.

In general, the low molecular weight simple monomers such as methyl methacrylate have a rather high shrinkage—about 20 per cent by volume. The substitution of groups having large molecular configuration, such as cyclohexanol, for the methyl group in the ester reduces the shrinkage to a workable value, and may, in addition, contribute other advantages such as greater hardness, higher softening point, and smoother polymerization.

The reduced shrinkage tends to reduce the strain in the finished optical element, thus helping to preserve homogeneity. But the polymerization must be uniform throughout the element, or other types of physical inhomogeneity resulting in optical inhomogeneity will result. To achieve this result the temperature must be uniform throughout the whole volume of the article during the entire polymerization cycle. This not only means that the heating must be uniform but that the temperature resulting from the exothermic polymerization reaction must be uniform as to distribution and controlled as to amount.

By careful attention to details, choice of suitable materials to be polymerized, using molds having good optical surfaces and properly mounted to take account of such contraction on polymerization as still occurs, excellent optical elements can be produced—slowly. A long polymerization cycle is necessary, and rather elaborate heating and cooling equipment must be used. But when certain aspherical surfaces must be produced in plastic, or when the reduced weight and lower fragility of plastic optical elements is desired, this is believed to be the best method at the present time.

Optical Properties

Other properties of plastic or resinous optical elements, however, may be more important than those of lightness, low fragility, and workability. The ordinary single lens, be it of glass or of plastic, suffers from a whole group of optical defects, however accurate the surfaces or however homogeneous the material of which it is made. Perhaps the most conspicuous defect is chromatic aberration—the inability of the lens to bring light of different wave lengths or colors to the same focus. Blue light is brought to a shorter focus than red light, and the image is surrounded by a halo of color. By the use of a double element lens this undesirable effect can be reduced. For a convex lens (one bringing parallel light to a real focus), a convex lens of crown glass and a concave lens of flint glass, used in conjunction, will greatly reduce this defect. The influence of the concave flint glass lens on the refraction of light of different colors is much greater than and opposite to that of the crown glass, so that a weaker flint element than the crown element can counteract, at least in part, the chromatic aberration (variation in focal length with color of light) and what is called an "achromatic lens" results.

But such a lens is not truly corrected for all wave lengths or colors of light. It is only partly corrected, for a more or less narrow range of colors, because the variations of the indices of refraction of the glasses available cannot correct for all colors but only for two colors. To correct for a wider range of colors a more complex lens system is necessary and usually more than two kinds of glass. Such lens systems are called "apochromatic." Other subsidiary advantages, moreover, result from the use of such complicated lens systems. Other defects such as coma, oblique astigmatism, spherical aberration, etc., are also reduced by varying the surface curvatures, thicknesses, lens separations, and other physical constants.

A single plastic lens element suffers from all the defects that a single glass lens does. But the relative refractive indices, and their respective variations with wave length, of two plastics of markedly dissimilar structure, such as polymethyl methacrylate and polystyrene, permit better color correction in a simple two-piece achromatic lens than two glasses. A two-piece achromatic lens results which is intermediate between the ordinary achromatic lens and an apochromatic lens—as far as color is concerned. Certain combinations of two plastic lenses will produce a larger aperture ratio than any two pieces of glass because of certain fortunate ratios of indices and dispersions. The other defects, such as coma, oblique astigmatism, and spherical aberration generally remain, except in so far as selection of curvatures of the limited number of surfaces may help to reduce them.

Interestingly enough, a combination of a glass lens element with a plastic lens element in an achromatic combination may be superior to a similar all-glass or similar all-plastic combination.

Where correction of coma, oblique astigmatism and spherical aberration is necessary or desirable in relatively simple lenses, the methods described may be applied to the molding or casting of plastic lenses in contact with mold faces having nonspherical surfaces, such as hyperboloidal, paraboloidal, ellipsoidal, or other shapes of surfaces. It is well known that the production of such surfaces in glass is extemely difficult. But once produced in the mold, a large number of duplicates can be made. The combination of such a correcting surface or surfaces with the desirable achromatizing properties of plastic probably will give very desirable results.

The high coefficients of thermal expansion of plastics—about ten times that of glass or most common metals—must be taken into account because local pressure, resulting from temperature change, may cause distortion in mounting or use.

One of the useful optical properties of a material is its light absorption, especially when the absorption is selective. Colored glass has, of course, been known for centuries. In fact, because of the coloring effect of impurities, not until comparatively recent times was glass obtained colorless. Plastics and resins, on the other hand, are quite color-free, because the monomers or other raw materials have to be highly purified in order to use them with consistent results under production conditions.

Colored glasses are produced by incorporating in the glass batch compounds of certain coloring elements, such as cobalt, sulfur, selenium, cadmium, copper, iron, nickel, silver, manganese, gold, etc. The color ob-

tained depends upon the composition of the glass used, the conditions of melting, and the subsequent heat treatment. Such colored glasses, besides their artistic and decorative use, are employed as selective filters in photography, spectroscopy, etc.

Incorporation of suitable dyes in plastics greatly enlarges the range of color obtainable, as well as making it possible to incorporate in the same filter several different absorbing ingredients, without interaction, to produce a color filter otherwise unobtainable in a single unitary article. By selecting a suitable solution of a coloring agent, most of the plastics and resins may be dyed, after fabrication, to produce color filters of complex shape.

If it seems that the drawbacks of plastics when used for their optical properties have been stressed, it is only to direct attention to some of their desirable attributes. Plastics still have much to offer. The longer one works with glass, the more one appreciates its limitations, and the same is bound to be true of plastics. And the law of diminishing returns is becoming very noticeable in glass development.

On the other hand, we have useful glasses ranging in index of refraction from 1.48 to 2.00, and, if we include some synthetic crystals such as lithium fluoride, from 1.39 to 2.00. Most transparent plastics and resins that are generally useful range from 1.49 (polymethyl methacrylate) to 1.70 (phenol formaldehyde) with polystyrene (1.57 to 1.59) in about the middle of the range.

More important than the index of refraction is the reciprocal relative dispersion or the variation of index of refraction with the wave length or color of the light, for different types of plastic, which permits the construction of achromatic lenses. Also important is what is termed the partial dispersion, or variation of the dispersion with wave length, such as the ratio of the red-green dispersion to the green-blue dispersion. Such variation is very rare in glass. Materials which differ markedly from existing optical materials in these two respects are greatly desired by optical designers. Because of their markedly different chemical composition, most of the transparent plastics and resins differ from the usual glasses in these two properties and merit further study.

Future Possibilities

There is a limited number of elements capable of combining to form glasses, although glasses themselves are complex mixtures. Most inorganic compounds and mixtures of compounds prefer to crystallize when cooled from a melt, rather than to stay transparent and isotropic. But in the organic compounds of high molecular weight that are termed "plastics" or "resins," the field is virtually unlimited. And when one considers the field of interpolymers, co-polymers, and mixed polymers, the possibilities are seen to be far greater. And then there are the possibilities of incorporating some compound, inert in so far as polymerization is concerned, miscible or soluble in the plastic or resin, to modify the optical properties in a desirable manner, or to increase the hardness, or to improve the casting or molding characteristics. Thus far most investigators in the field of plastics and resins have worked with the simpler compounds. Perhaps the time has come to prospect the field of complex mixtures.

Discussion

Mr. G. A. Olsen.[1]—Is not hardness one of the essential properties of plastics used for optical lenses?

Mr. H. R. Moulton (*author*).—Yes, but less important than homogeneity or dimensional stability.

Mr. Olsen.—What would your minimum hardness requirement be for plastics used in the manufacture of optical lenses?

Mr. Moulton.—The minimum hardness that can be used is not known. Homogeneity and dimensional stability are more important.

Harold L. Brouse.[2]—How do dimensional changes resulting from varying conditions of ambient temperature and relative humidity alter the optical characteristics of a three-or-four-element plastic lens when used in, say, a conventional camera application?

Mr. Moulton.—Properly mounted plastic lens elements are not believed to be adversely affected at normal atmospheric temperatures or relative humidities. Glass itself is subject to corrosive attack at high relative humidities.

[1] Bakelite Corporation, Bloomfield, N. J.
[2] Plastics Consultant, Crosley Division, Arco Mfg. Corp., Cincinnati, Ohio.

Low-Pressure Moldings and Laminates[1]

By T. Walter Noble[2]

Any discussion of the subject "Low-Pressure Moldings and Laminates" must, of necessity, be qualified due to the uncertain state of the industry at present, for it is extremely difficult to appraise or evaluate the field under existent conditions.

The first low-pressure phenolic resin was introduced to the plastics industry in 1941. While phenolic resins had been employed previously in the low-pressure range by processing under special treating conditions, this was the first time a low-pressure phenolic resin was offered as such. The low-pressure phenolic resin differs from the high-pressure type in having a lower volatile content for a given flow value than the more conventional type. This low-pressure type of phenolic resin had been under consideration for quite some time, but the development program was accelerated during the "defense" period of industrial activity prior to the recent World War.

The development of this resin was a definite contribution of our war effort as it permitted various types of equipment not suitable for the processing of high-pressure material to be used for the production of war matériel. Since existing high-pressure equipment was already heavily overloaded and such facilities could not be quickly expanded to meet the demands of our armed services, the new resin and equipment adaptable to processing it proved to be quite valuable. The equipment employed had obvious shortcomings of a mechanical nature. Some of it had not undergone any design changes for many years, and as a result was definitely antiquated. However, many thousands of parts were produced and were employed with very satisfactory results during the war period. The equipment employed with the low-pressure phenolic resin made it possible to produce parts which could not be produced at a comparable cost, and in some cases could be produced, regardless of cost, on the more conventional type of high-pressure equipment. For example, the hot press with an inflatable bag could mold undercuts in a split mold that could not be produced on a metal-to-metal mold at the same cost. By the use of sheet metal molds and rubber blankets, rather large fabrica-

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[1] Presented at the Symposium on Plastics at a meeting of A.S.T.M. Committee D-20 on Plastics held in Cincinnati, Ohio, March 4 and 5, 1947.

[2] Manager, Plastics Division, Fabricon Products, Inc., River Rouge, Mich.

tions could be produced in an autoclave that could not be produced in the conventional hydraulic press equipment of the compressor molder or high-pressure laminator.

While it had been assumed that such parts could not have physical properties comparable to those produced by high-pressure techniques (Table I), a comparison of the physical properties of cotton duck laminated by both high-pressure and low-pressure methods illustrates that values are comparable, except for impact and water absorption, which tend to be higher in the case of the low-pressure laminate. Electrical values of the low-pressure phenolic laminate are definitely lower than a high-pressure material, but in view of the fact that the material was never represented by the low-pressure laminator as being suitable for electrical applications there is no validity in criticism on this score.

Parts fabricated by low-pressure methods included airplane engine nacelles, wing tips, tail cones, parachute cases, covers of various types, helmet liners, fuel tanks, gyro compass covers, and many other parts.

Shortly after the low-pressure phenolic field was established, the Forest Products Laboratory announced the production of high-strength sulfite paper by the Mitscherlich process. This paper, when treated with a low-pressure phenolic resin of the penetrating type, resulted in a laminate having exceptionally high physical properties with tensile strength values exceeding 40,000 psi. and a high modulus of elasticity in tension. The characteristics and physical properties of this type of laminate are adequately discussed in several publications and will not be considered further here.[3, 4] This type of paper laminate found considerable application in semistructural plane parts, ammunition cases, airplane accessory parts, etc. One of the most important applications for this type of laminate was in its use as a washer in the proximity fuse. The requirements in this application were for exceptionally high dimensional stability and resistance to swelling when in contact with moisture. The low-pressure laminate performed very satisfactorily in this application.

The next resin introduced in the low-pressure field was a modification of the urea-glue type of resin, but because of its low resistance to moisture, brittleness, and tendency to heat decomposition, this material did not find acceptance in great volume as a low-pressure laminating material.

TABLE I.—COMPARISON OF PHYSICAL PROPERTIES OF LOW-PRESSURE MATERIAL COMPARED TO HIGH-PRESSURE MOLDED MATERIAL.

Based on Laboratory Specimens.

	Low Pressure	High Pressure
Material	8-oz. duck	8-oz. duck
Resin content, per cent	52	53
Molding pressure, psi.	200	1100
Compressive strength, psi.	38 500	40 000
Tensile strength, psi.	12 218	12 050
Flexural strength, psi.	21 900	20 605
Modulus of elasticity, psi.	933 000	900 000
Impact strength (energy to break), ft-lb.	0.475	0.35
Water absorption (24-hr. test)	3.10	1.2

The next type of resin to be introduced to the field was the contact or chemical glue type of resin. When first introduced, these materials were represented as being capable of molding at extremely low pressures and the term "contact resins" was applied to them. Because vacuum pressure was employed in some cases of processing, the term "negative pressure resins" was also employed. They are characterized by being 100 per cent reactive resins and cure without loss of weight; they range in viscosity from 20 to 600,000 centipoises, or from very fluid to a semisolid state; they are transparent, ranging in color from water-white to a straw color; and they can be activated by a variety of catalysts. In some cases, they have a very objectionable odor. Because their composition and physical properties can be varied over a wide range, they offer the laminator wide latitude as raw materials. By employing monomeric styrene as an extender, these materials may be varied in their wetting properties, viscosity and the price of the resin lowered considerably. Final properties of the resins vary from rigid to flexible, and in the rigid classification a self-extinguishing variety is available. It is possible to color these resins, by the use of dyes and pigments, over a fairly good scale of color. Catalysts for activation of the cure of the resin are of the peroxide type and and vary from liquids such as tertiary butyl hydroperoxide to solids such as benzoyl peroxide depending upon the application and properties desired in the cured material.

The chemical glue type of resin cures by polymerization rather than by chemical condensation as in the case of phenolic, urea, and melamine resins. Curing temperatures for the chemical glues range from 200 to 275 F. whereas the condensation type require 265 to 325 F. Because certain of the chemical glues, particularly the allyl type, are inhibited in the curing process by the presence of air, precautions must be taken to exclude air, usually by the use of an impervious membrane such as cellophane or polyvinyl acetate which is wrapped over the resin-treated material prior to curing.

In treating or impregnating by means of the different types of resin, the resin content on the web of base material is controlled in much the same manner for both types—usually by squeeze rolls or wiping bars which squeeze or scrape off the excess resin, leaving on the web only the desired amount. In the case of solution varnishes, such as the phenolics, the resin pickup may be further controlled by the addition of solvents to decrease the solids content of the varnish. After impregnating the chemical glue type of resin, to which catalyst has been added, the web is immediately ready for use without further processing. The condensation type of resin, however, requires evaporation of the solvent and condensation of the resin to a point where it will have the desired flow and volatile content for molding under established conditions. The latter process results in a dry web or sheet with a slight amount of phenolic odor. The former process produces a sticky web which has, in most cases, a highly objectionable odor. This type of material presents many problems in handling and is rather objectionable from a worker's point of view. The material has an advantage in lay-up assembly as it sticks quite well to itself and can be held in place without difficulty. Unfortunately, the quality of sticking is not limited to itself, and the material sticks to everything it touches. There are some polyester types available which are waxy rather than sticky, but these materials have not yet established themselves in volume. Newer types of contact resins have the desirable characteristic of sticking slightly to themselves but not to dissimilar materials.

Curing times for the chemical glues will range from 2 min. for some of the polyesters to 20 min. for some of the allyl resins in the same thickness. On a comparable basis the phenolics require 5 to 7 min., although special treatments have been made which have permitted cures of phenolics of approximately 2½ min. Low-pressure melamines will cure in 8 to 12 min. for the same thickness.

Storage life of treated materials varies widely. Catalyzed polyester and allyls usually are limited in storage life to approximately 2 days, although some allyl resins have been stored for 3 to 6 months. Newer types of contact resins will store for 2 to 4 months before definite changes are noted in molding quality. Treated phenolics

[3] "High Strength Laminated Paper for Aircraft," *Bulletin 1395*, Forest Products Laboratory, Madison, Wis.

[4] W. N. Findley, "Fatigue Tests of a Laminated Mitscherlich-Paper Plastic," *Proceedings*, Am. Soc. Testing Mats., Vol. 45, p. 878 (1945).

will store from 6 to 10 months, as will melamine resin treated materials.

Laminating pressures recommended for the chemical glues when they were first introduced were in the 25 psi. range as compared to 100 to 250 psi. for the low-pressure phenolic resins. However, it has been established that a marked improvement in properties is noted when the chemical glues are processed at 100 psi. and excellent properties are obtained when molded at 1500 psi. The previous statement is not intended to be facetious but is based on established facts and constitutes the basis of the author's reference to these materials as chemical glues when added in excess in the resin-filler ratio and processed at low pressures.

On molding or laminating the phenolic-treated materials, the treated sheets are placed between corrosion-resistant steel sheets to produce a flat laminate, or the die-cut pieces are loaded into the mold cavity. In some cases, the die-cut parts are stapled together for ease in handling and loading the mold cavity. Because the treated material is dry and the material essentially self-lubricating, a minimum of make-ready is required which tends to offset the longer curing time noted above when compared with the chemical glues. Molds are either of the metal-to-metal type or metal with an expandable bag or pressure membrane on the other side. The mold is usually heated by steam, direct gas flame, or electricity. After molding, the finishing operations include sawing, grinding, drilling, punching, painting or any other required operation.

The chemical glue treated material is processed in much the same manner except that lubrication of the mold by special lubricants is quite often required, and the customary use of an air-excluding membrane requires additional time for assembly. In view of the fact that the sticky material requires more time for lay-up assembly, this additional make-ready time tends to offset the advantage of faster cure of this type of resin. Molds for this resin may be made of plaster, wood, cast plastic, metal or any combination of these materials. Heating of the treated material may be accomplished by infrared lamps, heated ovens, steam, or electricity. Finishing operations are similar to those noted above.

During the war period, the contact pressure type of resin was employed almost exclusively with fillers of the inorganic type. This type of filler was wetted readily by the resin, and, because of the properties of the filler, moldings having exceptionally high strength values were produced and served very satisfactorily in a wide variety of end uses. Full data on the physical properties of this type of molding or laminate are available from a variety of sources.

Because of the types of molds employed, tooling costs were exceptionally low, and changes in the molds could be made rapidly and at low cost. This had a decided advantage in the war effort because of the many changes which were made in design of such items as plane parts as combat experience indicated a weakness in a structure or as engineering developments dictated a change.

As a result of the acceptance of parts molded in this manner during the war period, it was predicted that a large peacetime industry would be established based on production of products using the same materials and techniques as employed under war conditions. This prediction failed to take into consideration that the costs of the war program were underwritten by the United States Government and that the high material costs for resin and inorganic filler were generally disregarded as long as satisfactory performance was obtained. Temporarily, at least, the usual economic yardstick was discarded and end-use performance became the only criterion of value. When the normal economic laws once again became part of our business life, the high material costs could not be disregarded. In addition, the inexpensive molds did not stand up under long production runs, and as a result of a combination of these factors, the expected volume in this field failed to materialize, and as a result production has been confined to prototypes, models, and a few specialty uses. Apparently the engineering and tooling ability of proponents of this type of production did not match their enthusiasm and optimistic outlook which failed to include some very important and pertinent economic considerations.

Some effort has been devoted to attempts to employ cellulosic fillers and inorganic fiber mats to offset the high cost of woven inorganic filler. In the case of cellulosic fibers, the molecular weight of the chemical glues does not permit fiber penetration, with the result that low dimensional stability results. In the case of mat materials, the technique of handling is to load the dry filler into the mold and then to add the resin as a pour charge over the dry mat, after which a film of cellophane or other material is placed over the cavity charge and heat and pressure applied. Because of the excessive make-ready time required and in view of the fact that an excess of resin must be added to allow for good filling out of the mat, this PP and PM technique of molding appears to have serious economic disadvantages. A new technique of injecting the resin into the dry filler while it is in a closed and heated mold appears to have certain advantages which may provide a solution to the problem.

A very interesting technique of processing the chemical glue type of resin is that of continuous lamination. In this process a series of webs of paper, cloth, or fiberglas fabric are individually resin treated from separate treating pans and then laminated into a single ply by passing them simultaneously through squeeze rolls. At the squeeze rolls, a layer of cellophane is imposed on the top of the ply and another on the bottom and the composite web is passed into a heating oven. Longitudinal pressure is produced on the web—while in the oven—by differential speeds on squeeze rolls at opposite ends of the oven. Lateral pressure is produced by contraction of the cellophane, while held under tension by tenter frames, from the oven heat. The cellophane acts as supporting web, pressure pad, and, in addition, imparts a high finish to the laminate during the curing operation. This process has several advantages over the more conventional manner of laminating individual sheets in a hydraulic press, but recently disclosed figures indicate that the more modern hydraulic presses, when operated efficiently, produce laminated material at twice the footage per unit time compared to a continuous laminating machine. When a paper-polyester resin laminate of the type produced in this manner is compared to a melamine-surfaced phenolic laminate, it is found to be lower in surface hardness, less stain-resistant, and lower in abrasion resistance. The resins usually employed have lower heat-distortion points and because the molecular size does not permit good fiber penetration the dimensional stability of the laminates is rather low when compared to the melamine-phenolic type of material. This type of laminate, because it can be produced in any desired length, may possibly find application in wall panels and similar applications.

As new materials are developed and improvements in processing techniques are worked out for presently available materials, the field of low-pressure laminates and molding materials will undoubtedly find its proper place in the plastics industry.

Some Factors Affecting Adhesive Bond Formation

By H. P. Meissner[1] and E. W. Merrill[2]

It has long been the aim of workers in the field of adhesion to establish a basis for predicting not only what will stick to what, but for predicting the strength of the resultant bond. The object here is to consider some of the problems involved in such a study.

It appears desirable at the outset to reexamine the definition of an adhesive. McBain (**10**),[3] who pioneered in this field, pointed out that there are two types of adhesive bonds: mechanical and specific. Mechanical joints form by an interlocking or dovetailing of the adhesive into porous surfaces, while specific adhesion, which can occur on smooth as well as rough surfaces, evidently results from intermolecular and interatomic attractions between adhesive and adherend. Probably both mechanisms are present to some degree in every bond. McBain then further stated that any liquid which wets both surfaces and which can be solidified *in situ* will form a bond and is therefore an adhesive. He apparently considered an adhesive bond to form if the joint could withstand a tensile stress of any magnitude, however small.

This definition attributes three essentials to an adhesive: it must be a liquid, it must wet, and it must be capable of solidification. Equally interesting is what it not stipulated, namely, molecular weight, composition, and physical properties like coefficients of expansion. Moreover, no specifications regarding the adherend surfaces are raised. The evidence for this definition involved qualitative and quantitative tests of systems using as both adherends and adhesives a large number of materials of both high and low molecular weight and covering a substantial range of chemical and physical properties. In each case, the adhesive was applied in a liquid state achieved usually by melting, though solvents were sometimes used.

McBain's definition implies that wetting is a prerequisite to bond formation and raises the question of what is not an adhesive. Wetting has no universally accepted definition but is usually considered related to the contact angle between the liquid and the solid in question. It will be remembered that this can be regarded as the angle formed at the edge of a droplet by the liquid surface and the solid surface upon which this droplet rests and is always measured in the liquid. One school arbitrarily considers wetting to occur if the contact angle is less than 90 deg. and no wetting if it exceeds 90 deg. Another group considers complete wetting to occur if the contact angle is zero and that wetting is increasingly incomplete as the angle increases. Most organic materials, when liquid, form zero contact angles with clean metal and glass, and the cases investigated by McBain fall largely into this class.

To discover whether combinations of materials having high contact angles show no capacity for specific adhesion, a series of qualitative experiments were made of low molecular weight materials as adhesives by Callner (**4**) and Woodworth (**13**). To evaluate the possible importance of factors other than contact angles, combinations were also chosen showing large and small differences in melting points, polarities, hardness, coefficients of expansion, etc. In these tests, a small amount of adhesive material was placed upon the adherend surface and the combination heated slowly enough to keep temperature conditions uniform throughout the system to about 5 C. above the adhesive's melting point. The system was next cooled to about 10 C. below this melting point, whereupon formation of a bond was qualitatively investigated by prying off the droplet with a spatula heated to an equal temperature. The following materials were tested, including all those combinations in which the adherend had a higher melting point than the adhesive.

Adherends.—Bakelite, benzene, cellulose sheet, diphenyl, glass, ice, paraffin, polystyrene, steel.

Adhesives.—Calcium nitrate, potassium acetate, silver nitrate, sodium chloride, sodium thiocyanate, zinc chloride; lead and copper stearates; *n*-octadecanol; adipic, benzoic, oleic, and stearic acids; dioxan, *n*-octadecanol; dibutyl phthalate; aniline, benzophenone, nitrobenzene; benzene, cyclohexane, diphenyl, naphthalene, paraffin, phenanthrene; glass, mercury, water.

Bonds formed unmistakably in all cases. In many cases, of course, the bonds so formed could be destroyed by cooling to 100 C. below the adhesive's melting temperature, due to stresses resulting from unequal coefficients of expansion. The successful bonds formed by mercury are particularly interesting, since this material forms some of the largest known contact angles with ice, glass, styrene, etc. Bonds therefore formed here regardless of the magnitude of the contact angles involved.

In these tests, no extensive control of adherend surfaces was attempted, though they were as fresh, clean and smooth as possible. Despite all reasonable precautions, adsorbed layers of gases and water vapor, and probably traces of grease, were undoubtedly present, since no high vacuum tests were undertaken. Similarly, surface characteristics are influenced not only by age but by methods of preparation, a familiar example being the differences in metal surfaces depending upon whether they were prepared by grinding, milling, polishing, etc. Indeed, tests were deliberately undertaken on a given system in which different kinds of surfaces were prepared, and in which surface contamination as by oxidation was permitted. In all of these cases, bonds formed. As further evidence, the every extensive search made among others by Loughborough and Haas (**8**) to find solid surfaces to which water will not stick upon freezing deserves mention. This is of critical importance in de-icing of airplane wings during flight. No case of nonadhesion is reported in spite of the great number of materials tested.

While the evidence is not, of course, complete, the foregoing suggests that an adhesive bond will form if a low molecular weight material at a temperature above its melting point is brought into contact with a solid surface and is then allowed to freeze in place.

High Polymers as Adhesives

The capacity of thermoplastic high polymers to stick to solid surfaces when molten and then cooled to solidification is well known, and in this respect their behavior closely parallels that of low molecular weight materials. The tackiness often exhibited by molten polymers reflects this capacity to stick, as well as the reluctance of these polymers to flow resulting from their high viscosity.

Since a polymer usually does not show a well-defined melting tempera-

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[1] Associate Professor of Chemical Engr., Massachusetts Institute of Technology, Cambridge, Mass.

[2] Research Engineer, Dewey & Almy Chemical Co., Cambridge, Mass., formerly with Massachusetts Institute of Technology.

[3] The boldface numbers in parentheses refer to the references appended to this paper.

ture, the question arises as to whether a minimum temperature exists below which sticking becomes impossible. To explore this point, Judge (6) brought together various combinations of plastics and adherend surfaces at controlled temperatures. This was done by pressing together in a tightly fitting mold a thin foil of the adherend upon the flat face of a disk of the plastic under test, approximately $\frac{15}{16}$ in. in diameter and 0.2 in. thick. The entire apparatus was located in a thermostatic bath whose temperature was controlled to ±0.2 C. The system was of course first brought to temperature before pressure was applied, whereupon constant temperature was maintained throughout the test. Occurrence of sticking was determined qualitatively by pulling the foil from the disk. If sticking developed at a given temperature, the run was repeated at a new temperature approximately 2 C. lower until a minimum temperature was discovered at which sticking occurred but below which it did not occur. Table I presents the results using tin as an adherend. The evidence indicates that each polymer tested shows a unique temperature above which sticking develops but below which it rapidly becomes difficult and impossible to form a bond. For polystyrene, this temperature lies in the neighborhood of 80 C. and is evidently little affected by pressure. Above this temperature, the capacity for sticking develops rapidly, and indeed polystyrene becomes noticeably tacky to a light touch with a spatula at 110 C. Below 80 C., however, polystyrene quickly loses its capacity to stick even at prolonged exposure at high pressure to an adherend surface. Other plastics were found to behave in a fashion analogous to polystyrene. While Table I reports only results for tin as an adherend, entirely similar results were obtained for aluminum, cellulose, and styrene foil as adherends, whose minimum temperatures of bond formation were found to lie within 2 C. of that of tin.

Further inspection of Table I shows that the minimum sticking temperature for these polymers appears to coincide with their second order transition temperatures. It will be remembered that the second order transition temperature, a term coined by Ehrenfest (5), is defined as the temperature at which curves of primary thermodynamic properties like volume and enthalpy plotted against temperature show a discontinuity in slope. The values reported in Table I were determined on the materials tested by the use of a dilatometer designed according to Jenckel and Ueberreiter (7), with 20 min. allowed for each observation point.

TABLE I.—MINIMUM TEMPERATURES OF ADHESION TO TIN.

Adhesive	Second Order Transition, deg. Cent.	Time of Pressure Application	Pressure Applied, psi.	Minimum Temperature of Bond Formation, deg. Cent.
Polystyrene[a]	81	7½ hr.	10 000	75.5
		1 hr.	10 000	80
		5 min.	10 000	82
		10 hr.	50	80
		1 hr.	50	85
Polyvinyl butyral[b]	45	2 hr.	10 000	40
		10 min.	10 000	45
Polymethyl methacrylate[c]	53	1 hr.	5 000	50
		10 min.	5 000	65
Polyvinyl alcohol[d]	58	1 hr.	5 000	55
		5 min.	5 000	65

[a] Dow Styron, R-1-K27, GA type.
[b] duPont, V. F. 7100.
[c] duPont Lucite, SED 3633.
[d] duPont 52–22, Type A.

The curve for the polystyrene used here is shown in Fig. 1 and is typical.

These transitions have been very extensively studied, among others, by Boyer and Spencer (2), and are considered due to a rapid increase in rotational and vibrational freedom of the molecular chain segments at these temperatures. Thermoplastic polymers often (but not always) exhibit second order rather than first order transitions. A polymer's second order transition temperature is relatively unaffected by pressure but is lowered by solvent or plasticizer addition; this temperature rises with increasing molecular weight, but soon reaches a maximum constant value which is then independent of further molecular weight increases, providing no cross-linking occurs. Boyer and Spencer (3) showed that these second order transitions are not equilibrium effects, since the discontinuity in the curve of Fig. 1 disappears if 60 hr. instead of 20 min. are allowed for each observation point.

The coincidence of the minimum adhesion temperature and the transition temperature appears consistent with these facts. Adhesion undoubtedly requires a sufficient mobility of the atoms and molecular segments in the adhesive surface so that their force fields can key into the companion force fields of the adherend surface. Without such mobility and orientation, no perceptible bond formation can occur. Mobility increases as the temperature rises above the transition temperature but is rapidly lost below it, which explains why polystyrene shows a rapidly declining capacity to stick below 80 C. (see Table I). If mobility at a lower temperature is required, then this can be attained by reducing the polymer's transition temperature through solvent addition. Thus a nitrocellulose lacquer can be made to stick to metal surfaces far below the transition temperature of dry nitrocellulose, since the orientation required for bonding occurs before the solvent evaporates completely. On the other hand, mobility can be destroyed by raising the transition temperature through cross-linking. Thus, thermosetting resins used as adhesives are usually applied in partly polymerized form and then "set up" in place by heating, oxidation, etc. When applied in molten or solution form, orientation can clearly occur before extensive cross-linking destroys mobility. When applied as a dry powder or film, the polymer is usually made to melt before setting-up, and so again has an opportunity to orient. In all these cases, of course, a poor bond results if a film of low cohesive strength separates the

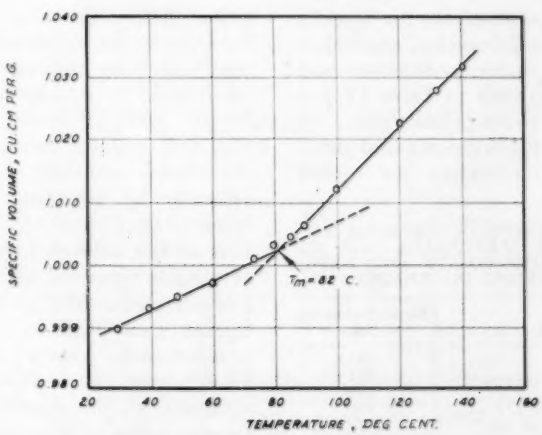


Fig. 1.—Specific Volume *Versus* Temperature for Polystyrene (11).

adherend and adhesive, such as the mold lubricants and parting agents used in molding.

The foregoing, therefore, suggests that a liquid will bond to a solid surface with which it is brought isothermally into contact if the combination is then cooled to below the transition temperature (either first or second order) of the liquid. A bond will of course also form if the liquid's transition temperature is increased above the system's temperature, as by cross-linking or solvent evaporation.

Bond Strength

While it has been suggested here that any liquid can be made to bond to any solid surface, the strength of the bonds so formed has not yet been considered. A great many factors have been recognized as affecting bond strength, and a few deserve brief discussion. It has, for example, been proposed that strong joints cannot be made to polar adherents with nonpolar adhesives, and *vice versa*. The experimental evidence for this generalization is not entirely satisfactory. Table II presents the test results of Loughborough and Haas (**8**), showing the shearing force needed to cause a button of ice to break loose from the indicated adherends, as determined in a centrifugal testing machine. Tables III and IV show Woodruff's findings (**13**) on the force required to shear off a button of the indicated adhesive 0.3 in. thick and 1.0 in. in diameter from a single adherend surface, by application of force parallel to this surface by means of a yoke which fits snugly around the adhesive button. The rate of loading was approximately 50 psi. per min. Results should be regarded as of comparative value only. The findings are evidently not consistent with the polarity criterion; for example, Table II shows ice, which is highly polar, to stick as well to polyethylene as to glass, which are respectively nonpolar and polar. The equal strengths for Wood's metal bonds to stainless steel and bakelite in Table III or for naphthalene and water to stainless steel in Table IV are again exceptions to the polarity rule. It is worth mentioning in passing that these bond strengths correlate no better with contact angles than with polarity.

TABLE II.—ADHESION OF ICE-FILM TO MISCELLANEOUS MATERIALS, −25 C. TESTS BY LOUGHBOROUGH AND HASS, BY CENTRIFUGAL TECHNIQUE.

Adherend	Shear Strength, psi.
Polished steel	185
Polished copper	124
24 ST aluminum	220
Glass (96% silica)	158
Microscope slide	122
Polyethylene	160
Rubber	170

It is not intended to imply here that the polarity rule is necessarily incorrect. These examples are cited to show that bond strength does not appear to depend solely upon one factor. Variables like coefficients of expansion and other physical properties must also be considered, since these may cause stress concentrations which weaken an otherwise strong bond, as discussed below.

Effect of Bond Thickness:

It has been known for a long time that bond rupture strength varies inversely and widely with thickness. A typical curve is shown in Fig. 2, showing results for a polymethyl methacrylate bond between two steel cylinders $\frac{13}{16}$ in. in diameter, stuck together end to end, and tested in tension at a loading rate of about 6500 psi. per sec. Each of the data points is the average of three tests. The bonds were formed isothermally at the various temperatures shown, by inserting a layer of molten polymer between the cylinders placed end to end, after which the bonds were cooled to room temperature for test. All care was exercised to keep the cylinders properly aligned while allowing the adhesive freedom to contract as it wished during cooling. The results show that bond strengths at room temperature appear independent of temperature of formation within the ranges investigated.

TABLE III.—ADHESION OF WOOD'S METAL (MP 62 C.) TO VARIOUS ADHERENDS, AT 50 C.

	Shear Strength, psi.
Glass	151
Lucite	84
Bakelite	46
Polystyrene	8
Stainless steel	37

Various explanations of this thickness-strength behavior have been proposed, and of these, four will be mentioned here. The first attributes this behavior to the development of stresses resulting from differences in thermal coefficients of expansion between adhesive and adherend. This theory was well restated recently by Turner (**12**), who proposed overcoming the difficulty by adjustment of the coefficient of the adhesive to correspond with that of the adherend by incorporation of suitable pigments and fillers. Figure 3 shows that unfilled polystyrene bonds thicker than 0.10 in. actually break spontaneously upon cooling, even though good bonds form initially, due evidently to the development of high stresses upon cooling. Filling the styrene with asbestine brings the coefficients of expansion of adhesive and adherend more closely into line, and so improves the thickness-strength behavior of the bond. The dips in the curves at small bond thicknesses are presumably due to "starvation" or to stresses resulting from compression of the particles of filler.

TABLE IV.—ADHESION OF VARIOUS MATERIALS TO STAINLESS STEEL.

	Melting Point, deg. Cent.	Test Temperature, deg. Cent.	Shear Strength, psi.
Naphthalene	80	55	90
Water	0	−20	78
β - Methyl naphthalene	35	14	63
Silver nitrate	212	190	48
Wood's metal	62	50	37
α - Methyl naphthalene	−22	−40 (?)	32
Lead stearate	116	62	30
Stearic acid	69	43	12
Paraffin	47	29	7
n-Octadecane	28	10	2

Further evidence indicating the influence of thermal stresses upon bond strength is presented in Fig. 4. Here is shown a typical curve of bond strength *versus* temperature of test at constant bond thickness for a thermoplastic polymer, in this case, polymethyl methacrylate. These tests, as before, were on metal cylinders stuck together end to end and tested in tension at a load rate of 6500 psi. per sec. The coefficient of expansion of the adhesive is roughly ten-fold that of the metal in this case. As the temperature falls, inspection shows that bond rupture strength increases until the second order temperature is reached. Here the rupture strength decreases abruptly, possibly because the material is no longer capable of rapid flow to remove strain inequalities. The strength again rises, reaches a maximum, and then falls off to zero as the internal thermal stresses become more and more important. Many cases of bond failure may be attributed to the development of such stresses. Figure 5 presents the same test data for unfilled and filled polystyrene. The benefits to be derived from adjustment of coefficients are evident.

A second explanation for the thickness-strength curves as in Fig. 2 attributes this behavior to differences in moduli, Poisson's ratio, etc., of adhesive and adherend. It appears that, even when thermal expansion coefficients are perfectly matched, unequal moduli of adhesive and adherend would still result in a curve qualitatively similar to Fig. 2. It will be noted that the curve for filled polystyrene in Fig. 3 still shows some variation of strength with thickness, and this may be due to differences either in the thermal coefficients or the moduli.

The so-called theory of flaws is a

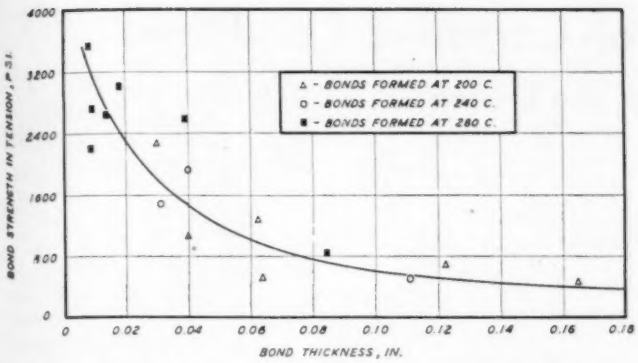


Fig. 2.—Bond Strength at 25 C. *Versus* **Thickness (11).**
Adhesive: polymethyl methylcrylate. Adherend: lathe-turned steel.

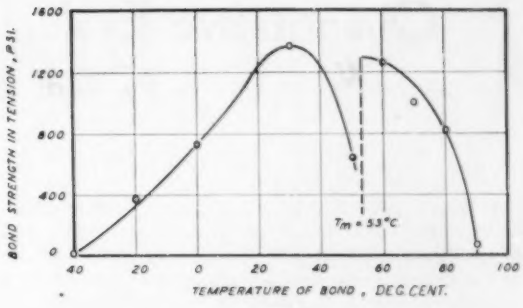


Fig. 4.—Bond Strength *Versus* **Temperature (11).**
Adhesive: polymethyl methacrylate. Adherend: emery-ground steel. These bonds were formed at 240 C., and were all 0.1 in. thick.

third possible explanation of the thickness-strength behavior of adhesives. This attributes the higher average strength of thin adhesive sections to the fact that these necessarily contain fewer structural flaws than thicker sections. Bikerman's (1) ingenious analysis of tests of paraffin wax bonds between metal blocks showed that this theory goes a long way toward explaining his experimental findings.

The fourth possible explanation of this thickness-strength behavior, proposed by McBain and Alexander (9), suggests that orientation occurs in adhesive films due to the influence of near-by solid adherend surfaces. McBain's X-ray study of glue films used as wood adhesive, however, uncovered no supporting evidence.

It will be noticed that these four possible explanations of thickness-strength behavior are not necessarily mutually exclusive, that is, all four may simultaneously affect bond strength. Only the last two theories mentioned offer a reasonable explanation for the fact that the strength of thin bonds may far exceed the cohesive strength of the adhesive material in bulk. The desirability of further work to establish the reasons for thickness-strength behavior is clear, since corrective measures can be taken only after causes are known.

References

(1) J. J. Bikerman, "Strength and Thinness of Adhesive Joints," *Journal* Soc. Chemical Ind., Vol. 60T, p. 23 (1941).

(2) R. F. Boyer and R. S. Spencer, "Advances in Colloid Science" (Mark), Vol. II, Ch. 1, Interscience Pub. Co. (1946).

(3) R. F. Boyer and R. S. Spencer, "Thermal Expansion and Second Order Transition Effects in High Polymers: Part III. Time Effects," *Journal of Applied Physics*, Vol. 17, p. 398 (1946).

(4) N. H. Callner, "Adhesive Behavior of Low Molecular Weight Materials," Massachusetts Institute of Technology Thesis (1947).

(5) P. Ehrenfest, "Phase Transitions," *Communications from the Physical Lab. of the Univ. of Leiden*, Supplement 75B, p. 8 (1933).

(6) M. B. Judge, "Minimum Adhesion Temperature of Thermoplastic Resins," Massachusetts Institute of Technology Thesis (1947).

(7) E. Jenckel and K. Ueberreiter, "On Polystyrene of Various Chain Lengths," *Z. Phys. Chem.*, Vol. A182, p. 361 (1938).

(8) D. L. Loughborough and E. G. Haas, "Reduction of Adhesion of Ice to De-icer Surfaces," *Journal of the Aeronautical Sciences*, Vol. 126, p. 13 (1946).

(9) J. W. McBain and J. Alexander, "Colloid Chemistry" (Alexander), Vol. III, Ch. 1, Interscience Pub. Co. (1931).

(10) J. W. McBain and D. G. Hopkins, "On Adhesive and Adhesive Action," *Journal of Physical Chemistry*, Vol. 29, p. 188 (1925).

(11) E. W. Merrill, "Certain Cohesive and Adhesive Characteristics of Thermoplastic High Polymers," Massachusetts Institute of Technology Thesis (1947).

(12) P. S. Turner, "Thermal Expansion Stresses in Reinforced Plastics," *Journal of Research*, Nat. Bureau Standards, Vol. 37, p. 239 (1946).

(13) C. L. Woodworth, "The Adhesion of Low Molecular Weight Compounds," Massachusetts Institute of Technology Thesis (1947).

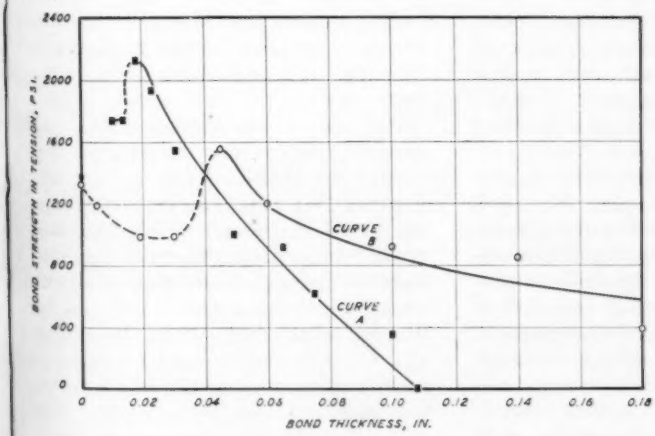


Fig. 3.—Bond Strength at 25 C. *Versus* **Thickness (11).**
Curve *A*: polystyrene without filler (cubical coefficient of expansion: 240 × 10^{-6} reciprocal degrees centigrade) bonded to lathe-turned steel surfaces (cubical coefficient: 33 × 10^{-6}).
Curve *B*: polystyrene filled with 60 per cent by weight of asbestine (cubic coefficient 114 × 10^{-6}) bonded to emery ground aluminum surfaces (cubic coefficient 75 × 10^{-6}).

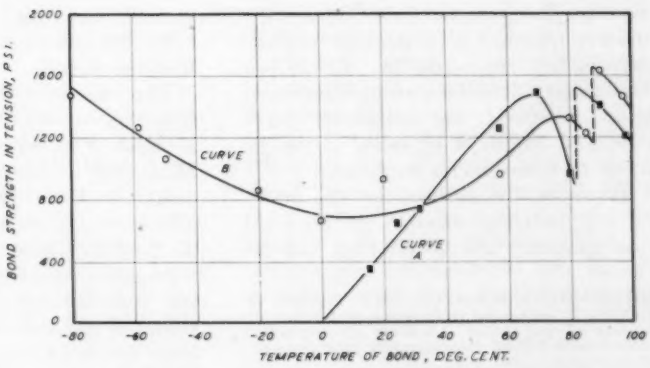


Fig. 5.—Bond Strength *Versus* **Temperature (11).**
Curve *A*: polystyrene without filler (cubic coefficient 240 × 10^{-6}), bonded to emergy-ground aluminum surfaces (cubic coefficient 75 × 10^{-6}).
Curve *B*: polystyrene filled with 60 per cent by weight of asbestine (cubic coefficient 114 × 10^{-6}), bonded to emery-ground aluminum (cubic coefficient 75 × 10^{-6}). All bonds were formed at 220 C., and were 0.1 in. thick.

Quantitative Evaluation of Corrosive Conditions

By W. F. Bonwitt[1] and I. Eisen[1]

SYNOPSIS

It was found possible to calibrate the effect of natural corrosion and of several artificial accelerated corrosion procedures on a metal by observation of the electrical resistance of a thin foil ribbon of the metal. With copper as the experimental sample, a linear relation was found between the duration of exposure to the corrosive procedure and the increase of resistance of the sample. This linear relation, which held true for natural corrosion and for all of the artificial procedures investigated, made it possible to develop a constant expressed as *percentage increase in resistance per unit time* for the effect of each corrosive procedure. From the data collected this *corrosive effect constant* was computed for each of the corrosive procedures investigated. The constant obtained for each process is significant, of course, only for the particular metal used for the foil. It is believed that further experiments will show whether this method can be applied to other metals and more complex conditions and to the quantitative evaluation of corrosive atmospheres present in various locations.

VARIOUS artificial procedures have been used in tests designed to simulate the effects of natural corrosion at an accelerated rate as a means for determining comparatively quickly the probable effects of natural corrosion on a sample under test. There is little basis, however, on which quantitative comparisons can be made between various artificial procedures and natural corrosive processes. The purpose of the work described was to investigate a sensitive means for making such comparisons. In this project the relative severity of a natural corrosive process and of three artificial procedures was determined. The rate of corrosion of metals has previously been measured by the increase of the electrical resistance of the metal. Burns and Campbell,[2] for instance, reported in 1929 on the use of this method for observing the corrosive deterioration of lead by acetic acid vapors. Snelling[3] used the resistance increase of a metallic layer to detect perforation of a paint coating covering the metal, and thus compared the relative qualities of protective coatings exposed to corrosive media. It was also found that a definite relationship seemed to exist between the resistance, diameter, and length of exposure of copper wires to atmospheric corrosion.[4]

However, the authors are not aware of any previous attempt to compare quantitatively the severity of various accelerated corrosion test procedures with each other, and with atmospheric corrosion. Rather, all previous work was concerned with a specific corrosive condition as it would affect a particular metallic sample. Since accelerated test methods are used more and more, a quantitative basis for comparison of different procedures seems essential.

The first step was to select a test sample of such a nature as to provide: (1) sensitivity to a wide range of degrees of corrosive effect, and (2) a significant, accurate, quantitative determination of corrosive effect as a change in a physical characteristic, after short increments of exposure time.

It was found practicable to measure corrosive effect in terms of increase of electrical resistance corresponding to reduction in cross-sectional area caused by corrosion of a corrosion-sensitive conductor. In order to provide maximum surface area with minimum cross-sectional area, the test sample selected was a metal foil ribbon. With such a sample, significant increases of resistance were obtained for small reductions in cross-section.

The corrosion-sensitive test sample used was a strip of copper foil 0.001 in. thick, 1 in. wide, and approximately 55 in. long. This copper foil ribbon was wound back and forth around two parallel rows of pyrex glass rods mounted on a Transite base. For measurement purposes, current was fed into the copper foil through two contacts, one mounted at each end of the Transite base which clamped around the ends of the foil. To prevent corrosion at the contacts, the clamps and the foil ends were solder coated. Potential terminals were provided by two wires soldered across the center of the outermost faces of each end of the foil and fixed to the Transite base.

PROCEDURE

Five test samples as described were prepared. Before assembly each foil was cleaned with carbon tetrachloride. Following assembly the length of foil between measuring points and the area of untinned foil exposed to corrosion were determined. Several resistance measurements were taken over an extended period to establish the initial resistance of each sample.

A standard measuring current of 0.1 amp. was used giving a current density of 100 amp. per sq. in. for the initial cross-sectional area of 0.001 sq. in. This current density was sufficiently low so that the heating effect of the current could be neglected. Measurements of resistance were made at standard conditions with a Leeds & Northrup precision Kelvin bridge.

After stable values for the resistance of the foil strips had been obtained in repeated measurements, the foils were subjected to various corrosive procedures, as described below.

Foil No. 1 was exposed to open air conditions (industrial atmosphere) in New York City. Resistance of this foil was measured at one-week intervals.

Foil No. 2 was subjected to a 24-hr. cyclic accelerated corrosion procedure. Each cycle consisted of 7 hr. exposure, in a test chamber at room temperature, to the mist produced by atomizing a 10 per cent aqueous sodium chloride solution with filtered air, followed by heating in an air oven for 45 min. at 125 C., followed by slow cooling to room temperature in the oven for the remainder of the 24-hr. cycle. This foil was measured at five-cycle intervals.

Foil No. 3 was subjected to a different 24-hr. cyclic accelerated corrosion procedure. Each cycle consisted of 7 hr. exposure, in a test chamber at 38 C., to the spray and mist produced by atomizing a 20 per cent aqueous sodium chloride solution with preheated, saturated air, followed by heating in an air oven for 45 min. at 125 C., followed by slow cooling to room temperature in the oven for the remainder of the 24-hr. cycle. This foil was also measured at five-cycle intervals.

Foil No. 4 was kept in the laboratory at room conditions as a control and was measured at one-week intervals.

Foil No. 5 was exposed continuously

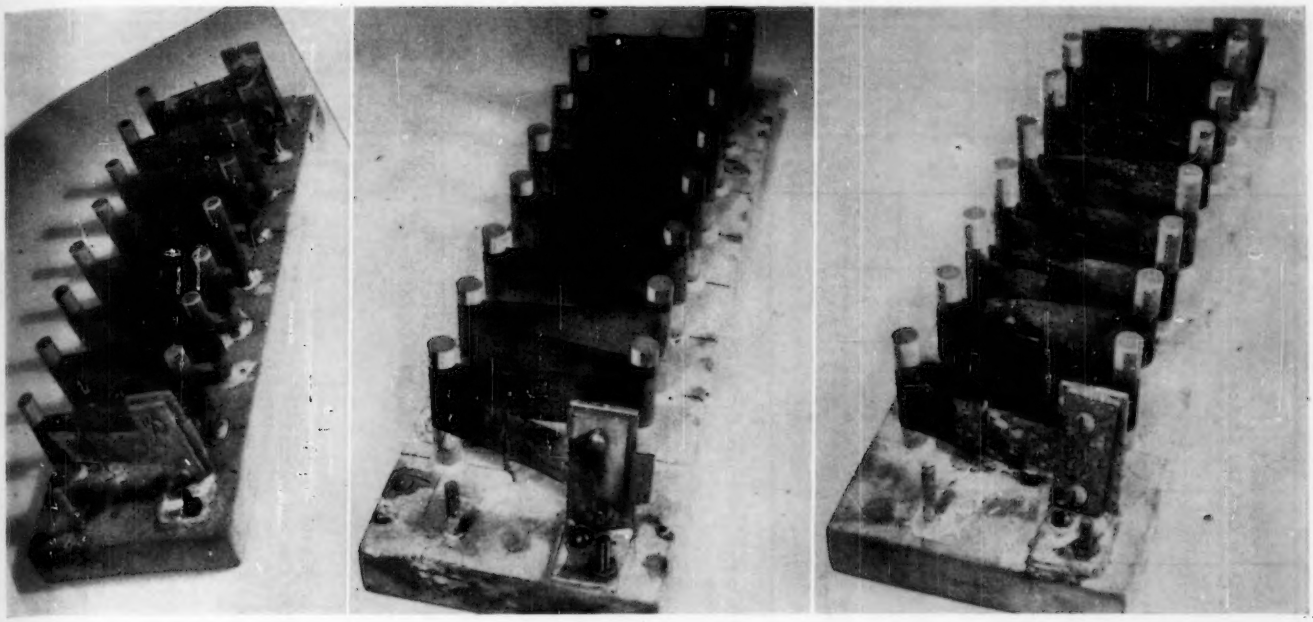
NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St. Philadelphia 3, Pa.

[1] Burndy Engineering Co., Inc., New York, N. Y.

[2] R. M. Burns and W. E. Campbell, *Transactions*, Am. Electrochemical Soc., Vol. 55, p. 271 (1929).

[3] U. S. Patent No. 1,811,765 (1931).

[4] J. C. Hudson, *Proceedings*, Physical Soc., Vol. 40, p. 107 (1927).



(a) Foil No. 2.—60 cycles, exposed to 10 per cent salt spray.

(b) Foil No. 4.—Unchanged after 6 months' exposure at room conditions.

(c) Foil No. 5.—21 days' continuous exposure to 20 per cent salt solution.

Fig. 1.—Effect of Exposure to Various Corrosive Procedures.

to the test chamber conditions at 38 C. described for foil No. 3. It was measured after each 24-hr. period and returned to the test chamber immediately.

Observations and Test Data

The visible effects of exposure to the various corrosive procedures are described below.

Foil No. 1, exposed to weather conditions, did not corrode to the point of mechanical failure. After eight months' exposure the surface was covered with soot and dirt. The foil itself was covered with black corrosion products, flecked with small green areas, and appeared smooth and uniform. No flaking of the oxide film was present.

Foil No. 2, subjected to 24-hr. cycles of exposure to the 10 per cent salt solution, failed after 60 such cycles. Large areas of the surface appeared to be undamaged while the remainder was covered with a light green corrosion product, identified as copper chloride. Only a very few small black spots were present. The appearance of the strip after failure may be seen in Fig. 1 (*a*). Failure occurred by tearing along one of the glass supporting rods as described below. Final failure was preceded by partial tearing at a number of the rods after approximately 45 cycles.

Foil No. 3, subjected to 24-hr. cycles of exposure to the 20 per cent salt solution, heating, and cooling to room temperature, failed after 39 such cycles. Light green corrosion products appeared after two cycles, and black spots after 10 cycles. The foil was completely black after 13 cycles. The oxide coating was coarse and flaky. Failure occurred by transverse tearing of the ribbon along the side of one of the glass supporting rods. The inner surface of the foil was protected against corrosion by the glass rods and the foil was thus thicker in the region which was in contact with the glass. A stress concentration occurred along the line where the foil was tangent to the glass, due to the sharp decrease in cross-section from that of foil corroded only on one side to that of foil corroded on both sides. In addition, condensed moisture may have accumulated in the crevices where the foil contacted the glass rods, causing particularly severe corrosion due to the air-water line. Rupture of the foil occurred along this line.

The shortcomings due to this particular mounting of the foil are recognized, and future work will be conducted with straight lengths of foil held in a frame.

Foil No. 4, kept at room conditions throughout the test, remained clean showing only a trace of oxide film. This foil was considered unchanged for the purposes of this investigation. Its appearance after approximately six months is shown in Fig. 1 (*b*).

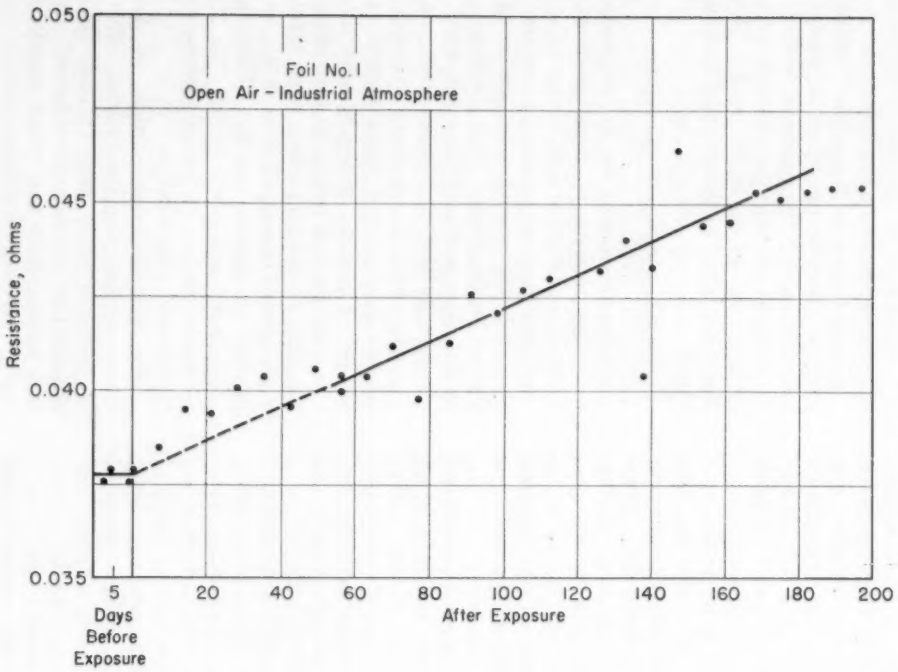
Foil No. 5, subjected to continuous exposure to the 20 per cent salt spray, failed after 240 hr. of exposure. During the first 24 hr., the surface of the copper became covered with patches of light green corrosion products, while the remainder of the surface remained bright. After this, black areas appeared and increased rapidly. After 72 hr. the entire surface was black, and it remainded in this condition until failure. The black corrosion product, cupric oxide, was coarse and formed flakes which chipped off, exposing a layer of red cuprous oxide underneath. Failure occurred by tearing at one of the glass supporting rods in the same manner as described for foil No. 3 above. The appearance of the strip at the time of failure is shown in Fig. 1 (*c*).

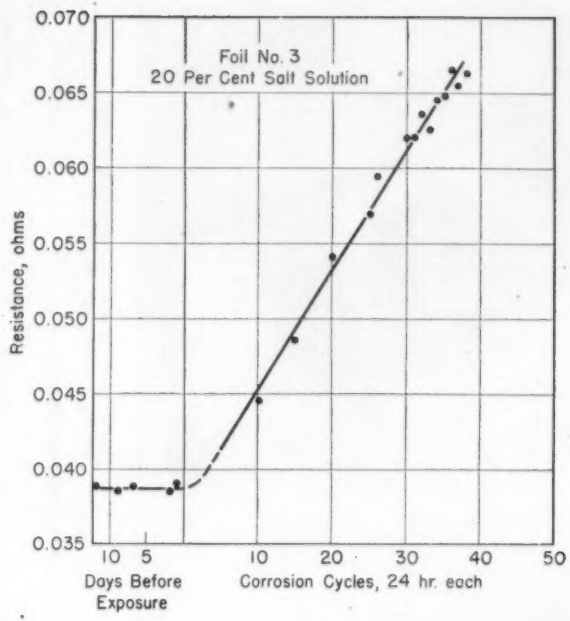
The test data, in the form of resistances of the foils measured at regular intervals during the progress of their exposure to the various corrosive procedures, are given in Table I. The data are plotted in the curves shown in Fig. 2.

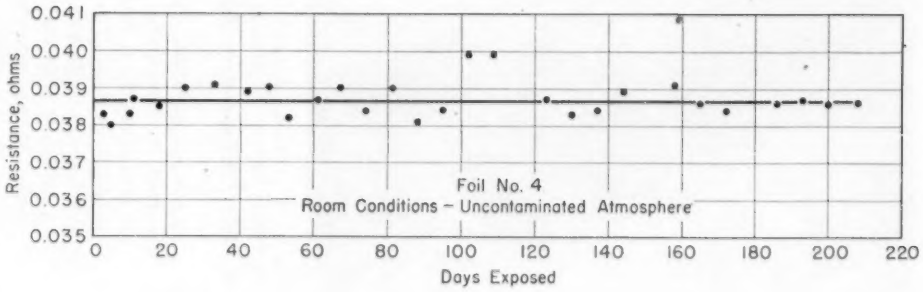
Discussion of Test Data

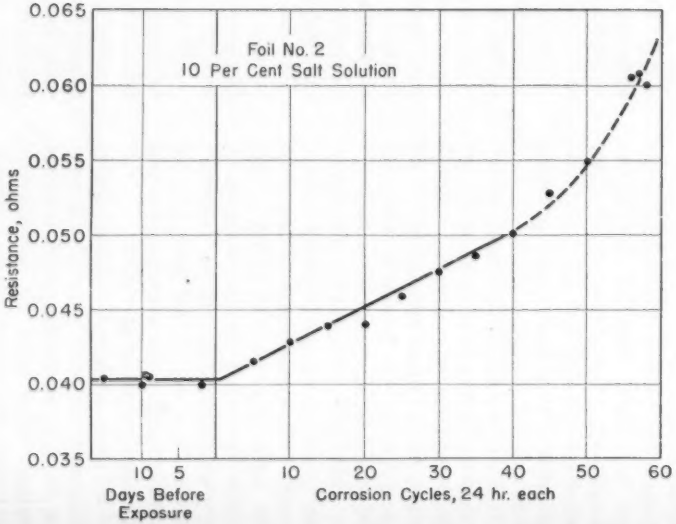
An examination of the curves shows that they consist of three portions. There is an initial period during which resistance increases erratically, presumably while the smooth, hard surface of the foil breaks down. This is followed by the major portion of the curve, which is essentially linear. This linear portion is produced by the constant reduction in cross-sectional area of metallic copper as the corrosion proceeds. Finally, whenever the foil begins to tear along the sides of the supporting rods, there is an upward change of slope as the resistance increases rapidly. This is particularly noticeable in foil No. 2, where a number of partial tears occurred before final failure.

The central, linear portions of the curves, representing the constant effect of corrosion, were used to make the quantitative determinations desired. It was known that the initial unstable region represents a definite part of the









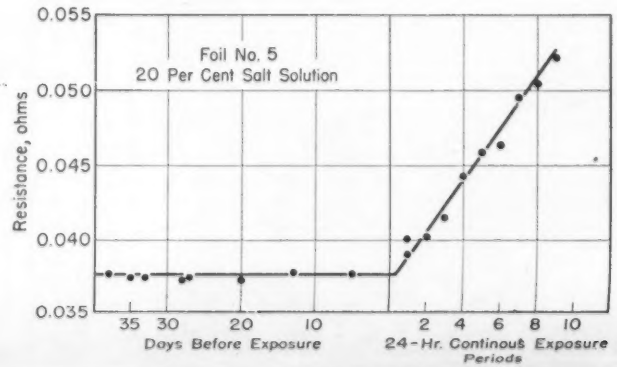


Fig. 2.—Resistance Under Test Conditions.

TABLE I.—RESISTANCE OF COPPER FOIL RIBBONS AFTER EXPOSURE TO CORROSIVE PROCEDURES.

Foil No. 1 Open-Air, Industrial Atmosphere		Foil No. 2 10 per cent Salt-Cyclic Corrosion Procedure		Foil No. 3 20 per cent Salt-Cyclic Corrosion Procedure		Foil No. 4 Room Conditions, Uncontaminated atmosphere		Foil No. 5 20 per cent Salt Continuous Exposure	
Resistance, ohms	Time, 24-hr. periods	Resistance, ohms	Time, 24-hr. periods	Resistance, ohms	Time, 24-hr. periods	Resistance, ohms	Time, 24-hr. periods	Resistance, ohms	Time, 24-hr. periods
Before Exposure		Before Exposure		Before Exposure				Before Exposure	
0.0380	0	0.0407	0	0.0389	0	0.0389	0	0.0377	0
0.0376	3	0.0404	2	0.0386	3	0.0382	3	0.0376	3
0.0379	5	0.0399	7	0.0389	5	0.0380	5	0.0376	5
0.0376	10	0.0406	8	0.0386	10	0.0383	10	0.0373	10
0.0379	11	0.0400	15	0.0391	11	0.0387	11	0.0376	11
After Exposure		After Exposure		After Exposure		0.0385	18	0.0373	18
0.0385	7	0.0415	5	0.0414	5	0.0390	25	0.0380	25
0.0395	14	0.0428	10	0.0446	10	0.0391	33	0.0380	33
0.0394	21	0.0439	15	0.0486	15	0.0389	42	After Exposure	
0.0401	28	0.0440	20	0.0541	20	0.0390	48	0.0390	1
0.0404	35	0.0459	25	0.0570	25	0.0382	53	0.0402	2
0.0396	42	0.0478	30	0.0594	26	0.0387	61	0.0416	3
0.0406	49	0.0486	35	0.0619*	30	0.0390	67	0.0442	4
0.0400	56	0.0501	40	0.0621	31	0.0384	74	0.0458	5
0.0404	63	0.0528*	45	0.0636	32	0.0390	81	0.0463	6
0.0412	70	0.0549	50	0.0626	33	0.0381	88	0.0495	7
0.0398	77	0.0606	56	0.0646	34	0.0384	95	0.0504	8
0.0413	84	0.0608	57	0.0649	35	0.0399	102	0.0522	9
0.0426	91	0.0600	58	0.0665	36	0.0399	109	failed	10
0.0421	98	0.0628	59	0.0655	37	0.0387	123		
0.0427	105	failed	60	0.0663	38	0.0383	130		
0.0430	112			failed	39	0.0391	158		
0.0428	119					0.0386	165		
0.0432	126					0.0384	172		
0.0440	133					0.0405	179		
0.0433	140					0.0386	186		
0.0464	147					0.0387	193		
0.0444	154					0.0386	200		
0.0445	161					0.0386	208		
0.0453	168								
0.0451	175								
0.0453	182								
0.0454	189								
0.0454	197								

* Indicates point at which partial tearing of foil was first noted.

effect of any corrosive procedure. However, it was felt that since this condition is a transitional one and is of short duration compared with the linear portion of the curve, it could be neglected. Thus the long-term effect of each corrosive procedure was expressed as a constant C equal to the increase in resistance per 24-hr. period, as a percentage of the initial resistance, thus:

$$C = \frac{R}{TR_I} \times 100$$

where:

R = resistance,
T = time in 24-hr. periods, and
R_I = initial resistance.

This formula, however, implies that the linear portion of each curve will pass through R_I if projected back through the initial unstable region. This could not be assumed (although it appears to be true for several of the foils tested). Therefore, the increase in resistance per 24-hr. period was determined from the actual slope of each curve, determined graphically from the linear portion of each plotted curve.

Thus C was determined from:

$$C = \frac{R_x - R_y}{(T_x - T_y)R_I} \times 100$$

where x and y represent points near each end of the linear portion of each curve.

It is interesting to note from the data for foil No. 1 that the continuous exposure to weather conditions also produced a constant rate of deterioration. The data show clearly the initial period, during which the surface breaks down, and the distinctly linear portion which follows.

Foil No. 4, which was retained as a control in an uncontaminated atmosphere at room temperature, remained practically constant in resistance throughout the duration of the test. This indicates that the corrosive effect constant for exposure under the control conditions may be considered as zero for purposes of comparison.

The values of the slope R/T for the linear portion of each curve, the initial resistance R_I of each foil, and the values of C obtained from these data are given in Table II.

TABLE II.—VALUES OF SLOPE, INITIAL RESISTANCE, AND CONSTANT C.

Foil	Process	R/T	R_I, ohms	Constant C
No. 1.	Outdoor exposure	4.46	0.0378	0.118
No. 2.	10 per cent salt mist cycle	24.3	0.0403	0.602
No. 3.	20 per cent salt mist cycle	79.7	0.0387	2.05
No. 4.	Room condition	0	0.0389	0
No. 5.	20 per cent salt continuous	176	0.0378	4.67

It is obvious that the comparative severity of the various accelerated corrosion procedures may easily be determined from these data. The 10 per cent salt mist chamber, for example, caused deterioration at five times the rate of natural corrosion, while the cyclic 20 per cent salt mist process was seventeen times as rapid in effect as natural corrosion, and the continuous 20 per cent salt mist process was forty times as rapid in effect as natural corrosion. A typical application of these data which has been used in the laboratory is in appraising the significance of results obtained with a comparatively rapid test procedure in comparison with those from a somewhat slower procedure. In practice, both exposure to thirty cycles of the 20 per cent salt mist cyclic procedure and 100 hr. of continuous exposure in the 20 per cent salt mist chamber have been used. It requires only a simple arithmetical calculation to determine that the 100-hr. continuous test is less than one-third as damaging as the 30-cycle test.

The question may also be raised, with reference to the 20 per cent cyclic process, whether the 45-min. heating period has any effect, or whether the entire corrosive effect is the result of exposure in the test chamber. This question is easily answered. For a total of 100 hr. the effect of the salt chamber alone is:

$$\frac{100}{24} \times 4.67 = 19 \text{ per cent}$$

increase of resistance, approx.

The 20 per cent cyclic process includes 7 hr. per cycle in the salt mist chamber. If the heating and subsequent cooling in the remaining 17 hr. of each cycle have no effect, then 14 cycles, giving a total chamber exposure time of 98 hr., should cause a resistance increase of approximately 19 per cent. Actually:

$$14 \times 2.05 = 29 \text{ per cent}$$

increase of resistance, approx.

It is therefore obvious that heating and cooling have considerable effect in increasing the rate of corrosion.

Conclusion

The procedure described here is suggested as an approach to the problem of the qualitative, comparative evaluation of the effect of various corrosive procedures. The data and results obtained are valid only for the corrosion of a copper test sample. The technique, however, can be improved and further tests should show whether it can be utilized to evaluate the rate of effect of various corrosive processes on dissimilar metals in contact, on a metallic plated surface, on an electrical joint, and upon other more complex combinations.

Even more important, this technique can possibly be adapted to general industrial use, as a means for evaluating quantitatively the deleterious effects of corrosive atmospheres present in industrial locations. The exposure, for a short time interval, of a small group of metal foil samples of known resistance, followed by measurement of resistance after exposure, may make possible an accurate prediction of the long-time effects of the particular atmosphere on metallic structures, electrical installations, etc., intended for service under the corrosive conditions.

Further investigation and experiment should make it possible to reduce the duration of exposure and to develop a standard test sample cell, more compact, and less susceptible to accidental damage than the type used here. It should also be possible to repeat this test using foils of metals other than copper, and thus to calibrate each corrosive process with several metals to obtain a profile of its effect. The development of a standard corrosion-sensitive sample or set of samples would be valuable in making possible the quantitative comparison of various artificial corrosion processes used in research and testing, and the evaluation of corrosive atmospheres encountered in the field.

A Versatile Calorimeter for Specific Heat Determinations*

By Harry Hill[1] and Raymond M. Bell[1]

The importance of the determination of specific heats of insulating materials is outlined in the introduction to a paper by Wilkes and Wood.[2] The time required for heating materials up to given temperatures depends inversely on the thermal diffusivity and directly on the square of the thickness of the material. The diffusivity is defined as the conductivity divided by the product of the specific heat and the density. Reliable tables of specific heats of certain insulating materials for wide ranges of temperature are not very complete. This work was carried out in order to provide more data on firebrick and other materials.

An adiabatic calorimeter was constructed and calibrated for measurements of the mean specific heats of five different kinds of insulating firebrick. The mean specific heats of the different brick samples were found to be about the same, ranging from 0.22 at a furnace temperature of 200 C. to 0.27 at a furnace temperature of 1000 C. The same calorimeter was used to measure the specific heats of four kinds of glass in about the same temperature range. The specific heats of these ranged from 0.24 to 0.30; but the number of readings taken was not sufficient to show locations of possible humps in the curves plotted between specific heats and temperature, or to show the points where the curves might flatten off. It was shown that the curve for glass is not so regular as that for firebrick. Calendered linoleum showed 0.35 at a furnace temperature of 70 C. and ranged to 0.4 at 143 C.

Apparatus

The design of the adiabatic calorimeter is based chiefly on the description given by Wilkes and Wood.[2] Its construction is shown in Figs. 1, 2, and 3. The cups available for making the jackets (*B*, *C*, *D* of Fig. 3) limited the size of the calorimeter (see *A* of Fig. 3, and Fig. 1), consequently temperature

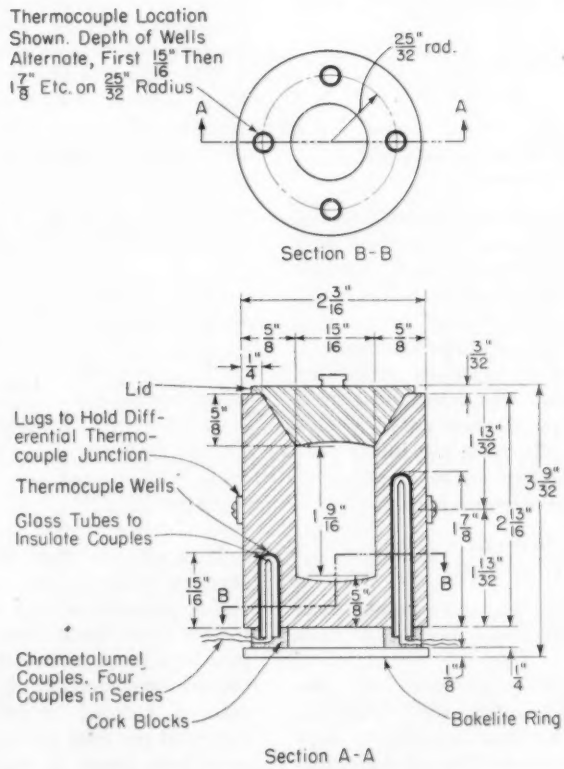


Fig. 1.—The Calorimeter (Cup *A*).

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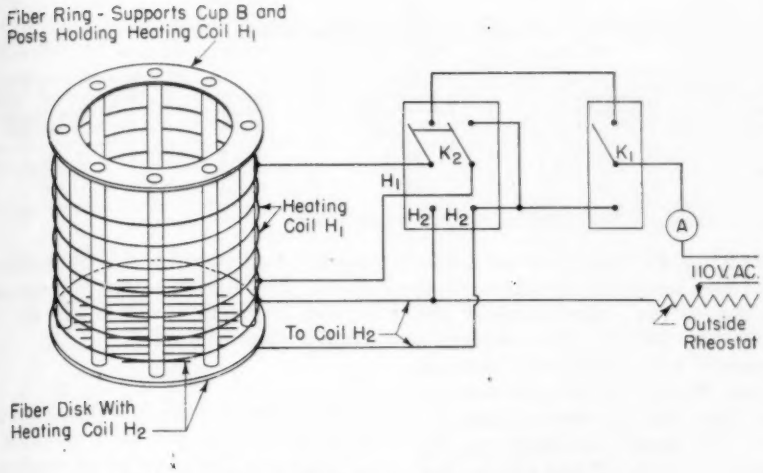
* This paper has been circulated in Subcommittee VII of Committee C-16 on Thermal Insulating Materials.

[1] Department of Physics, Washington and Jefferson College, Washington, Pa.

[2] Gordon B. Wilkes and Carl O. Wood, "Specific Heat of Thermal Insulating Materials," *Heating, Piping, and Air Conditioning*, Am. Soc. Heating, Ventilating Engrs., Journal section, June, 1942, p. 370.



Note: With Knife Switches in Up Position Coils H_1 and H_2 in Series, In Down Position, Coils H_1 and H_2 in Parallel for Greater Heating. Heating Unit Fits into Cup 3.

Fig. 2.—Equalizing Heater for Calorimeter.

rises greater than those commonly used in such measurements were encountered. It was considered advantageous in this case to control the temperatures of the water jacket by means of two equalizing heating coils (H_1 and H_2, Fig. 2) in the water. Each of these coils was made from 2.5 m. of No. 28 nichrome wire having a resistance of about 37 ohms. The framework shown in Fig. 2 which supports the coils fits into cup C. Coil H_1 supported on the upper part of the framework surrounds cup B. Coil H_2 consists of a few turns around the lower ends of the posts, but most of the wire is threaded through holes in the fiber disk below the bottom of cup B. The circuit connections are shown in Fig. 2. The switches K_1 and K_2 are fixed to the plywood box and are used to give either series or parallel connections of H_1 and H_2. When the switches are up the coils are in series. When they are down the coils are in parallel.

The insulating lid (Fig. 3) consists of layers of asbestos and bakelite with an aluminum foil reflector on the bottom. A small heating coil in this lid was used to control its temperature. The inside cup (Fig. 1, and A of Fig. 3) which was made of an aluminum alloy weighs 439.1 g. Four chromel-alumel thermocouples in series with a type K potentiometer were used to measure temperature changes in all of the determinations. These couples are in protecting glass tubes in the walls of the cup as shown in Fig. 1. These glass tubes are cemented to cork blocks which, in turn, are cemented to a very thin bakelite ring. The cup can be lifted out and replaced without disturbing the couples.

Two differential thermocouples are used to indicate the need for heater coil regulation. One of these couples is connected between the outside surface of the inside cup and the water jacket surrounding cup B (Fig. 3). The second couple is similarly connected between the inside cup and the heater in the insulating lid. These couples are connected alternately through a DPDT switch to a galvanometer with lamp and scale which gives a deflection of about 13 cm. for a difference in temperature of 1 C. During the determination the heater switches are manipulated to keep the galvanometer deflections as nearly zero as possible. The heaters require constant attention during a run. Coils H_1 and H_2 are connected in parallel to take care of rapid temperature changes such as occur when a sample is first dropped into the cup. The connection is changed to series when the state of temperature equilibrium is approached. Switch K_1 is used to open and close the circuit as the water jacket is kept at the rising temperature of the outer surface of the inside calorimeter cup. Each thermocouple wire and each lead to the equalizing heaters passes through separate holes in the lid collar so there is no danger of short circuits.

The furnace used for heating samples to temperatures ranging between 125 C. and 1000 C. is a thermostatically controlled Hoskins type FH204C with a Brown electric pyrometer. The recording of the Brown pyrometer was not dependable for reading the temperatures of samples in the furnace because its couple element is too far from the sample holder. Two thermocouples held in ceramic tubing extending through holes in the sample holder were always placed against the sample. These couples served as checks on each other and were read by means of a Leeds & Northrup portable indicator. The samples were heated in a small holder made of $\frac{1}{2}$-in. asbestos composition board. This holder could be removed rapidly from

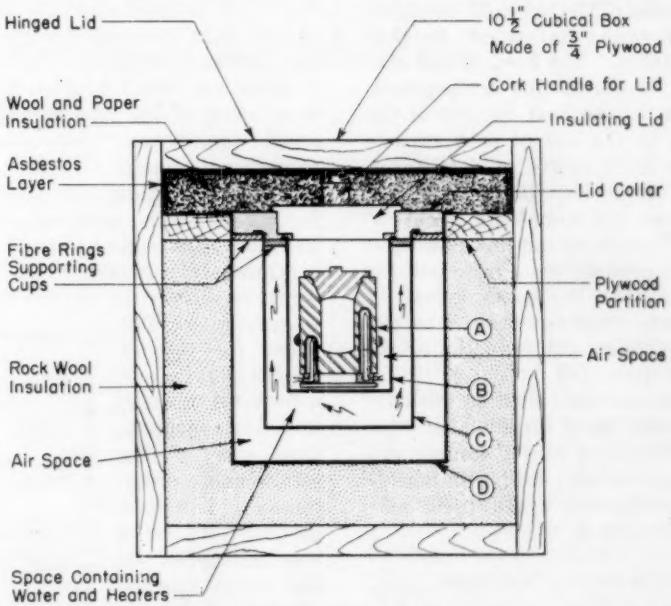


Fig. 3.—Insulation of Calorimeter.

the furnace and held over the open calorimeter as a sliding door at the bottom allowed the sample to drop into the calorimeter cup. Inasmuch as radiation losses occur from the holder only, errors in heat transfer are largely obviated except for those arising during the short time the calorimeter is exposed to the radiation from the hot holder and those arising from the very short time the sample loses heat due to convection currents and radiation just before it enters the cup.

Calibration

The calorimeter was calibrated by means of a small heating coil of nichrome wire of 9.78 ohms resistance at room temperature. The heating current used was about 500 ma. which was measured by a Weston milliammeter and checked by means of a potentiometer across a standard resistance. The average heat capacity of the calorimeter in calories per degree Centigrade was determined in a temperature range between 20 C. and 50 C. in steps of about 5 deg. The average of the results of 17 determinations came out to be 95.7 cal. per deg. Tests made on a sample of aluminum from the National Bureau of Standards gave fair results as shown in Table I.

Preparation of Samples

Samples of insulating firebrick and glass were prepared by packing about 10 g. of finely powdered material into capsules of aluminum or platinum foil. The thickness of the foil used was 0.001 in. and an empty foil capsule weighed less than 0.5 g. The kind of foil used depended on the furnace temperature. Correction for the heat content of the aluminum in the foil of each capsule was made from curves of data taken from the "Metals Handbook"[2a] and that for platinum foil from data given by White.[3] The use of foil and powdered brick samples was discontinued when it was found that the same values of specific heats could be obtained by use of small cylinders cut from the bricks and used without foil.

Thin flat materials such as linoleum were cut into small disks which were piled to the proper size of sample and then wrapped in foil. Burlap and sheeting were made into small tight rolls and wrapped in foil.

Experimental Procedure

Each sample of brick or glass was always kept in the furnace for five or six hours before a determination was made. The furnace temperature varied about 10 C. due to the overshooting of the controller at 500 C. The maximum temperature held practically constant for about 10 min. and samples were removed from the furnace within this period. At lower temperatures the difference between off and on was not so great after it was learned from practice what current to use in the furnace heaters to prevent overshooting. Both the calorimeter and the furnace thermocouples were read just before the sample holder was removed from the furnace. Two operators were always needed to make a quick transfer of the sample from the furnace to the calorimeter, one to handle the sample holder and the other to close the calorimeter lids and to start manipulating the equalizing heater switches. The time of transfer was about four seconds. The time required for the calorimeter to reach equilibrium temperature after receiving the sample was from 40 min. to 1 hr. This time was not the same for all materials measured. The galvanometer spot light had to be watched continuously, otherwise the heaters would be allowed to become too hot or to remain too cold. When the thermocouple emf. became constant it was read and the temperature rise of the calorimeter determined. This temperature difference was multiplied by the mean thermal capacity of the calorimeter and the result divided by the fall in temperature of the sample times its mass to arrive at the mean specific heat between the two temperatures. If the sample was one wrapped in foil, correction was made for the heat content of the foil.

TABLE I.—ALUMINUM TESTS.

Furnace Temperature, deg. Cent.	Initial Calorimeter Temperature, deg. Cent.	Final Calorimeter Temperature, deg. Cent.	Observed Specific Heat	Specific Heat from Heat Content Curve from "Metals Handbook" for Same Range[a]
203	22.4	34.4	0.237	0.230
108.2	21.0	26.5	0.226	0.226
109.6	19.5	25.3	0.228	0.226

[a] "Metals Handbook," 1939 Edition, Am. Soc. Metals, p. 1242.

TABLE II.—MEAN SPECIFIC HEAT OF INSULATING FIREBRICK. (5 KINDS OF BRICK.)

Furnace Temperature, deg. Cent.	Initial Calorimeter Temperature, deg. Cent.	Final Calorimeter Temperature, deg. Cent.	Observed Specific Heat
208	21.2	25.1	0.220
332	24.8	31.4	0.229
444	22.1	31.3	0.237
605	23.9	38.4	0.247
769	23.2	40.6	0.256
934	23.1	44.8	0.262
1060	21.4	47.0	0.268

Results

Insulating Firebrick.—The variation of results from one kind of brick to another was found to be so small that average values of specific heats were used in plotting the curve (Fig. 4) and in calculating true specific heats. Table II shows the mean specific heats and furnace temperatures for averages of five kinds of insulating firebrick. Figure 4 is a plot of these data.

TABLE III.—SPECIFIC HEAT DETERMINATIONS ON GLASS SAMPLES.

Sample	Furnace Temperature, deg. Cent.	Final Calorimeter Temperature, deg. Cent.	Observed Specific Heat
A	342	29.9	0.237
	461.3	33.9	0.244
	608.1	39.5	0.263
	747.3	47.4	0.282
	896.7	54.7	0.293
	934.5	58.3	0.306
B	342	31.6	0.233
	467.3	34.7	0.244
	608.1	41.5	0.257
	737.7	46.7	0.286
	896.9	*55.4	0.299
C	342.8	29.6	0.234
	460.4	32.7	0.241
	601.8	37.1	0.255
	738.0	47.5	0.282
	902.2	53.3	0.290
D	342.5	30.8	0.239
	464.9	32.9	0.245
	608.2	38.7	0.263
	749.2	49.8	0.288
	889.5	56.5	0.300

The equation for the true specific heats of firebricks was found to be:[4]

[4] For a method of calculating the constants see Sackur, "Thermochemistry and Thermodynamics," Ch. II, Macmillan and Co., London (1917).

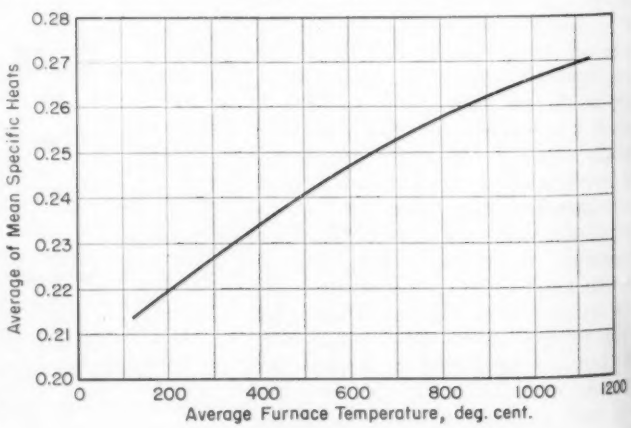


Fig. 4.—Insulating Firebrick.

[2a] "Metals Handbook," 1939 Edition, Am. Soc. Metals, p. 1242.

[3] W. P. White, "The Specific Heat of Platinum at High Temperatures," *Physical Review*, Vol. 12, p.436 (1918).

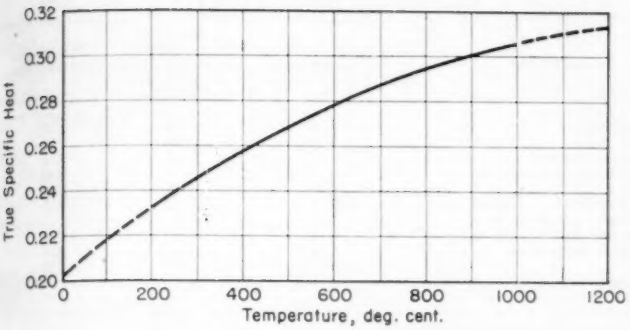


Fig. 5.—Insulating Firebrick.

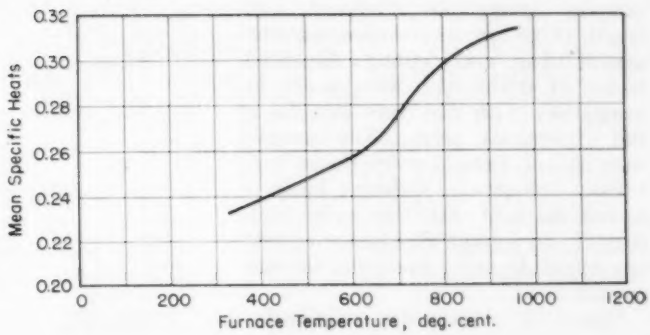


Fig. 6.—Glass.

$$C_t = 0.20885 + 1.5900 \times 10^{-4}t - 5.625 \times 10^{-8}t^2$$

C_t is the true specific heat at a temperature of t degrees centigrade. This equation is shown by Fig. 5.

Glass.—The specific heats of glass samples showed greater variations from a regular curve than those of firebrick, and was expected.[5] The greatest variations in the results of these samples seemed to come between 600 and 700 C. The number of readings taken was not sufficient to determine the location of possible humps in the curves or the place where the curve might flatten off. Table III records the data for four glass samples. Figure 6 is typical for glass samples.

[5] G. W. Morey, "Properties of Glass," Ch. VIII, Reinhold Pub. Co., New York, N. Y.

Calendered Linoleum and Various Other Materials.—Preliminary determinations were made of the specific heats of raw burlap, plain white sheeting, and calendered linoleum at lower temperatures and temperature ranges than those used for brick and glass. There was uncertainty in results due to changes in weights of these substances during heating. Raw burlap and plain white sheeting yielded values of about 0.4 at furnace temperatures below 100 C., but fell lower at higher temperatures due, perhaps, to greater changes in moisture content. Careful weighings were made of each sample before and after each determination to show the loss in weight. The linoleum lost much less weight than other materials measured. Sample results are shown in Table IV.

TABLE IV.—CALENDERED LINOLEUM TESTS.

Furnace Temp., deg. Cent.	Final Temp., deg. Cent.	Difference	Mean Specific Heat	Percentage Loss of Weight
70.2	26.0	44.2	0.351	1.1
91.0	24.6	66.4	0.371	0.25
122.0	30.5	91.5	0.391	1.2
142.7	35.3	107.4	0.399	1.85

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Measurement of Volume Resistivity of Electrically Conducting Rubber-Like Material

By R. F. Miller[1]

SYNOPSIS

Electrically conducting rubber is being used in many applications where the poor conductivity of ordinary rubber compounds or other materials allows dangerous static voltages to exist. A few of these uses are: hospital operating room flooring, anesthesia masks and tubing, tires, belts, De-Icers, self-sealing fuel cells, and heels and soles for shoes. Frequently these applications require materials having resistivities below 10^5 ohm-cm. Early attempts to make control measurements of these materials were frequently inconsistent because of equipment or technique. The measuring equipment described here has been designed to eliminate the errors arising from contact resistance and high power density. The effects of voltage gradient, contact pressure, and some of the effects previously attributed to mill grain are thought to be a part of the contact resistance problem. Errors due to contact resistance are eliminated by the use of separate current and voltage electrodes. Two circuits using this electrode system are described: one for direct current measurements and the other for alternating current measurements. The specific impedance (impedance in ohm-cm.) of conducting rubber at 60 cycles per second is shown to be the same as the d-c. resistivity from 1 ohm-cm. to 10^7 ohm-cm. The measuring technique is also considered as a source of errors from flexing, relative humidity, and temperature.

SOURCES OF ERROR IN MEASURING CONDUCTING RUBBER-LIKE MATERIAL

Contact Resistant:

THE measurement of the electrical resistivity of rubber-like materials, particularly below 10^5 ohm-cm., has often resulted in considerable error because of contact resistance.[2] This problem arose apparently because measurements of conducting rubber-like materials were undertaken with equipment designed for measuring high-resistivity materials where a large dimension factor, the ratio of area to length, aids in extending the upper limit of resistivity which can be measured. For this reason, the sample shape was frequently a disk having a dimension factor in the order of 500 cm., based on an electrical path length of 0.2 cm. and a cross-sectional area of 100 sq. cm. (See A.S.T.M. D 257 – 45.)[3] For the reduction of contact resistance error the electrical path length should be greatly increased and the cross-sectional area reduced. Strip type

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[1] Physical Research Lab., The B. F. Goodrich Co., Akron, Ohio.

[2] R. G. Newton, *Journal of Rubber Research*, Vol. 15, p. 35 (1946).

[3] Standard Methods of Test for Insulation Resistance of Electrical Insulating Materials, 1946 Book of A.S.T.M. Standards, Part III-B, p. 135.

samples having an electrical path length of 15 cm. and a cross-sectional area of 0.5 sq. cm., yielding a dimension factor of 0.033 cm., were made for comparison with disk type samples of the dimensions given. The samples were rubber, natural or synthetic, with various amounts of different kinds of carbon black.[4,5] For this early work, current and voltage were measured with one set of Aquadag electrodes on each sample.

Figure 1 shows the relationship between resistivities based on disk and strip type samples of six compounds varying in resistivity from 7 to 19,000 ohm-cm. The resistivities agree above 10,000 ohm-cm. However, as the resistivity decreases below this, the disk resistivities bear an increasing ratio to the strip resistivities, reaching almost 100-fold at a resistivity of 10. Two sources of this deviation have been considered—contact resistance and grain effects. Several observations point to contact resistance for most of the difference in these samples. If the deviation resulted from a differing resistance in the sample as a function of the relation of the direction of current flow to the direction of milling it would not necessarily be expected to become uniformly less important as the resistivity increases. However, the effect of contact resistance would be expected to follow such a pattern, especially when it is realized that a disk sample resistance of 0.02 ohm must be measured to result in a resistivity of 10 ohm-cm. while the strip value would be 300 ohms. Aluminum disk samples with two Aquadag electrodes gave 0.1 to 1 ohm resistance. This would give a resistivity of 50 to 500 ohm-cm. for aluminum, whose resistivity should be 2.8×10^{-6} ohm-cm. Hence to insure an electrode error of less than 1 per cent with Aquadag on disk samples as described, the resistivities should be greater than 50,000 ohm-cm. Metal electrodes molded on the sample give somewhat better results, but corrosion at the interface becomes an important factor. Furthermore, there is never complete assurance that the sample and electrode are in continuous contact.

TABLE I.—EFFECT OF TYPES OF ELECTRODES ON DISK SAMPLE RESISTANCE.

Sample	Electrodes	Resistance in Ohms of Disk Sample and Two Contacts	Calculated Resistance in Ohms for Disk Sample from Strip Values	Dimension Factor, cm.
6-2	Sprayed lead	3.1	1.06	228
6-3	Sprayed lead	9.0	1.04	233
6-7	Sprayed aluminum	1.17	1.05	231
6-9	Lead foil and petrolatum	50	1.01	239
6-11	Aquadag	11	1.07	227
7-13	Sheet aluminum—molded on	100	0.62	263
3-19	Sheet zinc—molded on	4.9	2.7	273
3-20	Sheet zinc—molded on	5.4	2.6	286
3-21	Lead foil—molded on	2.4	3.0	248
30-6	None	1160	..	223
30-6	Aquadag	3.1	..	223

Samples 6-2 to 7-13 are plasticized polyvinyl chloride loaded with acetylene black. Samples 3-19 to 3-21 and 30-6 are carbon-black loaded natural rubber stocks.

In Table I, resistances measured on disk samples with various types of electrodes are compared with resistances calculated for the disk from measurements made on strips. The sprayed lead and aluminum electrodes were applied to the samples by impinging small molten particles against the surface and building up a layer in a period of several minutes so that the temperature rise of most of the sample was minimized. The lead foil was adhered either by rolling it on with a thin layer of petrolatum or by molding it on with heat and pressure during the cure of the sample. Sheet aluminum and zinc were also molded on. The 6-11 Aquadag result agrees with Fig. 1 giving about 10 times as much resistance through a disk as the value calculated for this configuration but based on measurements on a strip. The sprayed lead results are lower and the sprayed aluminum gave a measured resistance within experimental error of the value calculated from measurements along the "grain" on a strip. This again indicates that the apparent differences in resistivity with direction of current flow are often the result of high and inconsistent contact resistance with disk samples of low resistivity. Sheet aluminum molded on gave a very poor contact, perhaps due to an oxide layer.

A second factor which can result from contact resistance in disks is the effect of contact pressure shown in Table II. Increasing the pressure from 8.8 to 150 g. per sq. cm. continuously decreased the measured resistance of the disk which had a resisitivity below 4600 ohm-cm. The same variation of contact pressure has less effect as the true resistivity increases.

A third factor indicating contact resistance is the effect of changing the voltage applied to the sample. Disk samples of low resistivity which show a diminishing resistance with increasing contact pressure likewise show a decreasing resistance with increasing voltage. This can be explained by arcing

TABLE II.—EFFECT OF CONTACT PRESSURE.

Sample	Contact Pressure, g. per sq. cm.	Resistance of Disk Sample, ohms	Resistivity, ohm-cm.
6A....	8.8	19.7	..
	44	11.9	..
	88	10.5	..
	150	8.6	4600

6A is a carbon-black loaded natural rubber stock. Disk 11.4 cm. diameter. Aquadag electrodes. 0.188 cm. thick. Dimension Factor = 543 cm.

[4] D. Bulgin, *Transactions*, Inst. of the Rubber Ind., Vol. 21, p. 188 (1945).
[5] P. E. Wack, R. L. Anthony, and E. Guth, *Journal Applied Physics*, Vol. 18, p. 456 (1947).

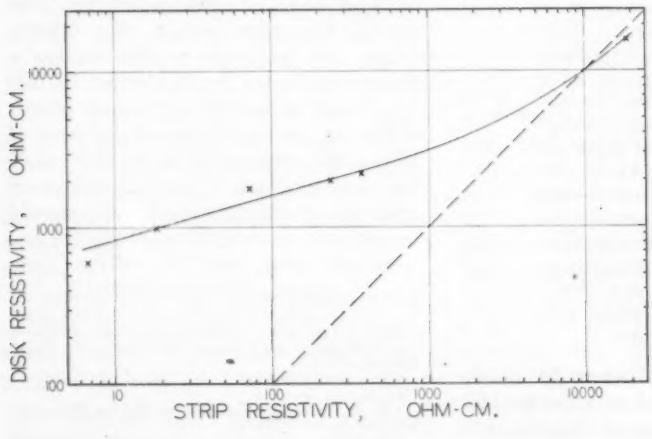

Fig. 1.—Comparison of Resistivities of Disk and Strip Samples.

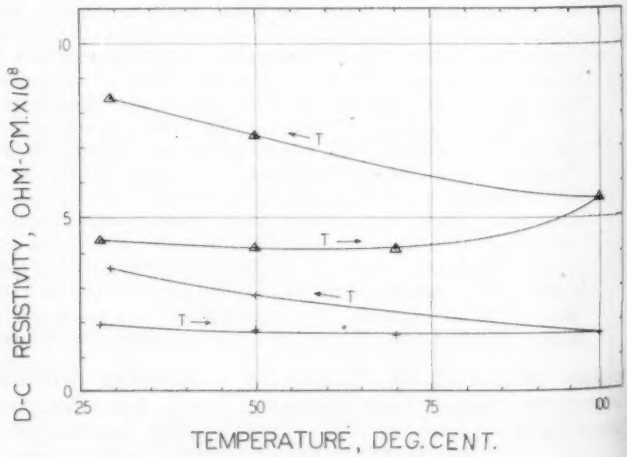

Fig. 2.—Resistivity-Temperature Curves.

at poor contacts. The arc voltage drop becomes a smaller proportion as the applied voltage is increased so that the resistance of the sample and its contacts decreases. The measurements on sample 31-2 in Table III show that variation of the voltage gradient over four decades has a negligible effect on strip type samples.

Relative Humidity, Flexing, Temperature, and Power Density:

Relative humidity has a small effect on the measured resistivity, as shown in Table IV. Samples were exposed to and measured at the humidity shown. Exposure to the 60 per cent relative humidity was at least 29 hr. The 22 and 31 per cent relative humidities were room conditions. Resistivities between 10^6 and 10^7 ohm-cm. showed an average of only 10 per cent drop in resistivity at 60 per cent relative humidity as compared to their resistivity at 31 per cent relative humidity. Resistivities below 5.26×10^5 ohm-cm. show no change with relative humidity between 22 and 60 per cent. This seems reasonable for a surface conductivity effect.

Flexing produces marked changes in the resistivity of conducting rubber-like materials. Table V shows typical increases in resistivity as a result of flexing and recovery after rest periods. Sample 715-10 was a tube 17 cm. long, 3 cm. inside diameter, and 0.25 cm. wall thickness. One end was clamped to a stationary support while the other was clamped to a support bearing which was rotated at 30 rpm. around a circle of 18 cm. diameter. The fixed end was on a perpendicular through the center of this circle. After 2211 revolutions, it showed an increase in resistance of 13 times. After a rest period of 92 hr., this sample still had a resistance 5 times the unflexed value. Sample 30-1 shows increasing resistivity as it is cut into narrower strips between 2.54 and 0.64 cm. This arises from the larger proportion of the sample which is flexed when cut with the shears. Buffing the surface for cleaning or dimensioning has a similar effect. Apparently, then, the flexing history must be consistent if comparable results are to be obtained in a series of samples.

If the temperature of the sample is varied, the resistivity of conducting rubber varies in a somewhat unpredictable manner as indicated by Fig. 2. The lack of return to original values may be due to increased cure or possibly to flow. This points to the need for testing at a constant temperature. Some control must also be exercised to limit the temperature rise due to the measuring current through the sample. Reference to Table III shows that power densities in sample 31-2 from 4×10^{-9} to 4×10^{-1} watts per cu. cm. caused less than 2 per cent change in the resistivity. The highest power density 4×10^{-1} watts per cu. cm., would cause a temperature rise of about 10 C. per minute. Sample 4071 showed an 8 per cent change in resistivity as the power density was increased from 1.7×10^{-2} to 6.4×10^{-1} watts per cu. cm. Sample W8 was held at constant voltage and an initial power density of 7.9 watts per cu. cm. which is sufficient to produce a temperature rise of 200 C. per minute, assuming no heat loss. The sample went through the resistance changes shown in the four minutes before it cracked apart and arced visibly. These data indicated a maximum allowable power density of around 0.25 watts per cu. cm. for measurements requiring less than one minute.

TABLE IV.—EFFECT OF RELATIVE HUMIDITY ON RESISTIVITY.

Sample	Resistivity, ohm-cm.			Ratio, 60% RH to 22 or 31% RH
	22% RH	31% RH	60% RH	
4A	.....	5.79×10^6	5.51×10^6	0.95
4C	.....	1.60×10^7	1.47×10^7	0.92
4E	.....	4.34×10^6	4.00×10^6	0.92
5A	.....	1.76×10^7	1.40×10^7	0.80
12D	.....	1.58×10^6	1.42×10^6	0.90
A	2.22×10^5	.....	2.18×10^5	0.98
B	2.61×10^5	.....	2.57×10^5	0.98
C	5.26×10^5	.....	5.35×10^5	1.02
M29	0.98×10^9	.....	1.02×10^9	1.04

Samples were natural rubber - carbon black recipes. Dimensions: 0.2 by 15 by 15 cm. Circuit and electrodes of Fig. 4.

TABLE V.—EFFECT OF FLEXING AND RECOVERY ON RESISTIVITY.

Sample	Cycles of Flexing	Recovery, min.	Resistance, ohms	Resistivity, ohm-cm.
715-10	0	.....	4 600	..
	2 211	20	59 000	..
		32	55 000	..
		180	44 000	..
		92×60	25 000	..
	10 000	21	140 000	..
		32	110 000	..
		180	75 000	..
		42×60	44 000	..
30-1	2.54 cm. wide strip—cut one edge		.....	203
	2.54 cm. wide strip—cut both edges		.....	265
	1.27 cm. wide strip—cut both edges		.....	281
	0.64 cm. wide strip—cut both edges		.....	1010

TABLE III.—EFFECT OF VOLTAGE GRADIENT AND POWER DENSITY.

Sample	Volts per cm.	Watts per cu. cm.	Sample Resistance, ohms	Resistivity, ohm-cm.
31-2	0.0011	4×10^{-9}	6000	300
	0.011	4×10^{-7}	6000	....
	0.11	4×10^{-5}	6000	....
	1.8	1×10^{-2}	6000	....
	3.5	4×10^{-2}	6000	....
	11.	4×10^{-1}	5900	....
4071	0.131	1.7×10^{-2}	4.00	1.02
	0.265	6.8×10^{-2}	4.04	1.03
	0.414	1.6×10^{-1}	4.20	1.07
	0.557	2.9×10^{-1}	4.17	1.06
	0.840	6.4×10^{-1}	4.32	1.10 warm
W8	7.4	7.9	181	6.96
	7.4	6.6	215	8.27
	7.4	5.6	254	9.77
	7.4	6.3	224	8.62
	7.4	8.6	165	6.36
	7.4	12.6	112	4.32

31-2 was a strip, 12.7 cm. long, 2.54 cm. wide, 0.251 cm. thick. Dimension factor = 0.0503 cm. Common E and I electrodes of Aquadag.
4071 was a strip 7.50 cm. long, 7.37 cm. wide, 0.259 cm. thick. Dimension factor = 0.255 cm. Separate E and I electrodes. 6.4×10^{-1} watts per cu. cm. caused a temperature rise of 20 C./min.
W8 was a strip 15.2 cm. long, 2.54 cm. wide, 0.230 cm. thick. Dimension factor = 0.0385 cm. Common E and I electrodes of Aquadag. This sample burned and blistered at the end of the 4-min. current flow durng which these data were taken.

Elimination of Errors Due to Contact Resistance

Electrodes:

Contact resistance is the largest source of error not directly under the control of the operator. In order to eliminate this error, the principle of separate current and potential electrodes shown in Fig. 3 was tried. This method has long been used for conductivity measurements in metals, and it is equally effective in the measurement of conducting rubber-like materials. The final electrodes developed in this work consist of two pairs of current electrodes and two potential electrodes all made of stainless steel and mounted on a hard rubber base plate with a hingled top. Two of the 1 × 1 × 18-cm. current electrodes are mounted on the base with their inner edges 11 cm. apart. The potential electrodes are knife edges, 5.5 cm. apart, symmetrically placed

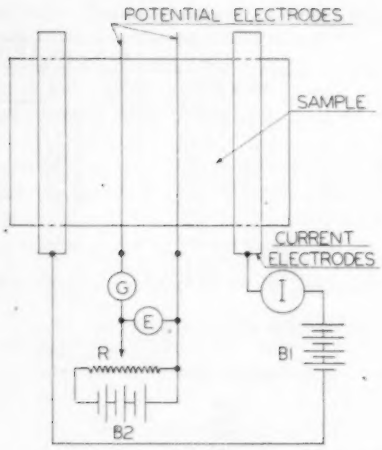

Fig. 3.—Basic Circuit Using Separate Current and Potential Electrodes.

in the plane of the contact surfaces of the bottom current electrodes. The hinged top superimposes current electrodes on top of the sample for additional contact area. This design accommodates any sample having a length of at least 13 cm. (clear of all sample identification imprints), a width less than 18 cm., and a thickness up to 0.5 cm. A 2-lb. insulated weight holds the sample against the potential electrodes, and a 10-lb. weight holds the current electrodes against the sample. The use of Aquadag current electrodes on the sample gives somewhat more consistent results if the samples are not dimensionally uniform.

Using this electrode system, resistivity measurements were made with direct current as well as with alternating current.

Direct-Current Method:

In Fig. 3 this electrode arrangement is shown schematically with two independent battery sources, *B1* and *B2*, for current and voltage measurements. The current required by the voltmeter *E* is furnished by the battery *B2*. This voltage is made equal to the sample voltage between the potential electrodes by adjustment of *R* and observation of galvanometer *G*. This galvanometer should be such that it will detect a current less than one-tenth the smallest sample current.

Figure 4 shows an equipment based on Fig. 3, but using two sets of current and potential batteries to extend the range to 10^7 ohm-cm. so as to overlap other resistivity equipment in use here. The 3-v. current source must be capable of supplying 2 amp. A 10,000-ohm resistance limits the current drawn from the 135-v. source to 13.5 ma. A single 20-microampere, 3-in. panel meter is used for current, voltage balance, and voltage reading by switching *S2*. Six current ranges are provided by the Ayrton shunt *S4*. The 1G4G tube is used to protect the meter by limiting accidental overloads to 150 per cent of full scale. Two 500,000-ohm resistances replace the grid resistance to prevent circuit voltage changes caused by switching the grid circuit from current to voltage measurements.

An upscale current of 30 microamperes is established in the meter through the 5000-ohm meter damping resistance by adjustment of *R2*. The no-signal plate current of the 1G4G is set to 30 microamperes down-scale by adjustment of *R4*. The *R4–R6* network also provides degeneration to improve linearity. Current and voltage from the sample are fed to the tube as negative grid signals so that an extreme overload can only raise the meter current to 30 microamperes.

In operation the current reading is made first. *S4* is left on the shunt position used for the current reading while the voltage balance and voltage readings are made because of the voltage drop in the Ayrton shunt. This drop also creates a 5 to 1 instead of a 10 to 1 increase in meter reading as *S4* is advanced from one position to the next when the 3-v. current source is used. The batteries in the tube circuit should be replaced when they fall below 1.4 and 42 v. A photograph of the test set and electrodes of the d-c. apparatus is shown in Fig. 5.

Alternating Current Method:

A considerably simplified circuit recently has been built in which the specific impedance is measured with 60 cycles per second alternating current. Calculation shows that this is the same as the d-c. resistivity because the 60 cycles per second capacitance current will be less than 1 per cent of the resistance current if the dielectric constant is below 100 and the resistivity is below 2×10^7 ohm-cm. Batteries are not required and a commercial vacuum tube voltmeter can be used to read the a-c. voltages involved. The need for independent current and voltage sources is eliminated by the use of two balances to determine the voltage drop along the sample.

The circuit diagram is given in Fig. 6. A 120-v. 60 cycle per second source is used with a 1:1 isolating transformer capable of handling 15 w. Leakage resistance and capacitive reactance from the secondary to the core and to the primary must be high compared with the resistance of *R1* and *R2*. Using 10,000 ohms for these two voltage balancing resistors, the transformer requirements were met as satisfactorily with a dry type service transformer as with an electrostatically shielded isolation transformer. *R5* limits the sample power dissipation below 0.1 w. per cu. cm. if the sample is 0.25 by 13 by 15 cm. *R3* and *R4* limit the off-balance currents encountered in making the voltage balances.

The standard Ayrton shunt has 10,000 ohms total resistance and multipliers of 1, 0.1, 0.01, 0.001, and 0.0001. The vacuum tube voltmeter uses a-c. power

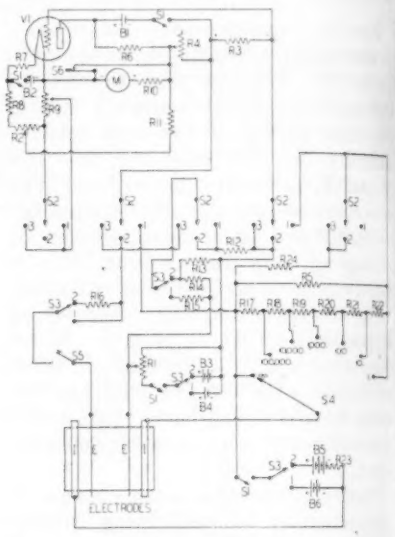

Fig. 4.—D-C. Resistivity Measuring Circuit.

Controls:

S1	On-off switch. 4 poles.
S2	Meter switch. 5 poles, 3 positions. Position 1—Read current. Position 2—Balance voltage. Position 3—Read voltage.
S3	Voltage selector. 4 poles, 2 positions.
S4	Ayrton shunt switch. 1 pole, 7 positions.
S5	Voltage balancing key.
S6	Meter key.
R1	Voltage balancing potentiometer.
R2	Zero adjuster.

Values of Components:

R1	100,000 ohms wire-wound resistance, 25 w.
R2	200 ohms wire-wound, 5 w.
R3	500,000 ohms carbon, 1 w.
R4	50,000 ohms adjustable wire-wound (set approx. 30,000).
R5	750,000 ohms carbon, 1 w.
R6	350,000 ohms carbon, 1 w.
R7	2 ohms wire-wound, 1 w.
R8	10,000 ohms carbon, 1 w.
R9	1500 ohms adjustable wire-wound, 10 w.
R10	500 ohms carbon, 1 w.
R11	5000 ohms carbon, 1 w.
R12	500,000 ohms carbon, 1 w.
R13	75,000 ohms carbon, 1 w.
R14	1×10^7 ohms carbon, 1 w.
R15	220,000 ohms carbon, 1 w.
R16	4×10^7 ohms carbon, 2 w.
R17	1 ohm adjustable wire-wound, 25 w. (set 0.9 ohm).
R18	10 ohms adjustable wire-wound, 10 w. (set 8.1 ohms).
R19	100 ohms adjustable wire-wound, 10 w. (set 81 ohms).
R20	1000 ohms adjustable wire-wound, 10 w. (set 810 ohms).
R21	10,000 ohms adjustable wire-wound, 10 w. (set 8100 ohms).
R22	81,000 ohms (made up of 1 w. carbon resistances).
R23	10,000 ohms carbon, 2 w.
R24	500,000 ohms carbon, 1 w.
M	20 microampere d-c. meter.
V1	1G4G tube.
B1	45-v. battery. Plate and grid circuit.
B2	1.5-v. battery. Filament circuit.
B3	112.5-v. battery. Potential measuring circuit.
B4	1.5-v. battery. Potential measuring circuit.
B5	135-v. battery. Current source.
B6	3-v. battery. Current source.

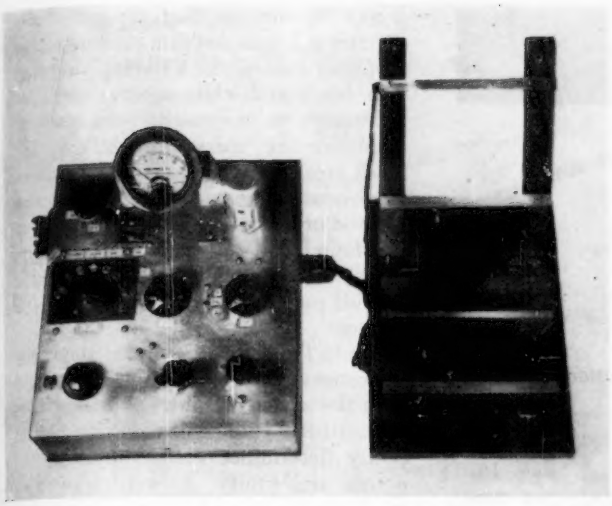

Fig. 5.—Test Set and Electrodes for D-C. Measurement of Resistivity.

so that one terminal must be grounded. This ground is carried around the circuit with the voltmeter as shown for the current measurement, the voltage balances, and the voltage measurement. The meter used has an input impedance of 10^6 ohms resistance and 15×10^{-12} farad, with voltage ranges of 0.03, 0.1, 0.3, 1, 3, 10, 30, 100, and 300 v. full scale.

Leakage currents were reduced by shielding the lead from the shunt to the current electrode, the shield being connected to the other side of the shunt. A grounded aluminum sheet was placed under all of the apparatus. A final leakage current of 5×10^{-8} amp. was considered satisfactory for measurements up to 10^7 ohm-cm., which involve currents greater than 100×10^{-8} amp.

The measurement procedure differs from that used in the d-c. circuit only in that two voltage balances are made. To limit the wattage dissipated in the Ayrton shunt, its *LL* resistance is kept low enough so that it introduces a voltage drop of not over one volt. By balancing the *R1* arm to the potential of the right potential electrode and the *R2* arm to that of the left potential electrode, the voltage between *R1* and *R2* is equal to that between the potential electrodes on the sample. This avoids connecting the voltmeter ground directly to a potential electrode on the sample which would then ground the circuit leakage currents through the sample.

TABLE VI.—COMPARISON OF A-C. IMPEDANCE AND D-C. RESISTIVITY.

Sample	d-c. Resistivity, ohm-cm.	a-c. Specific Impedance, ohm-cm.	a-c./d-c.
A5	1.58×10^7	1.55×10^7	0.98
D4	5.53×10^6	5.49×10^6	0.99
E4	4.82×10^6	4.80×10^6	1.00
C12	2.66×10^6	2.58×10^6	0.97
B12	2.40×10^6	2.43×10^6	1.01
F43	2.14×10^6	2.19×10^6	1.02
F34	1.66×10^6	1.67×10^6	1.01
A90	2.57×10^4	2.55×10^4	0.99
617	5.08×10^2	4.98×10^2	0.98
B613	2.01×10^1	2.02×10^1	1.00
C282	2.46×10^0	2.51×10^0	1.02
M92	9.55×10^{-1}	9.78×10^{-1}	1.02
		Avg.	0.999

Circuits: Fig. 4 and Fig. 6, modified. See text.

Comparison of A-C. and D-C. Measurements:

In the comparison of the a-c. specific impedance measurement with the d-c. resistivity, considerable care was taken to reduce reading errors and changes in the samples themselves. A circuit was set up so that both the a-c. and d-c. measurements could be made on a given sample without removing it from the electrodes. This eliminated errors due to changes in relative humidity and flexing. The power dissipation in the sample during the measurements was low enough to insure that both measurements were made at the same temperature. For the d-c. measurements, a calibrated galvanometer was used which was capable of being more accurately read than the 20-microampere meter. The a-c. accuracy was limited by the commercial vacuum tube voltmeter. This instrument was calibrated against more accurate voltmeters, but it was difficult to read to within 2 per cent of full scale.

Table VI shows that the a-c. specific impedance agrees with the d-c. resistivity within 3 per cent for all samples compared in the range from 1 to 10^7 ohm-cm. These data are for rubber-carbon black samples, but we have no evidence to indicate that the a-c. specific impedance of other materials in this range will not agree with the d-c. resistivity. In view of this, the a-c. method is preferable because it requires no batteries or d-c. power supply. Furthermore small a-c. voltages can be measured more consistently with a vacuum tube voltmeter than can small d-c. voltages.

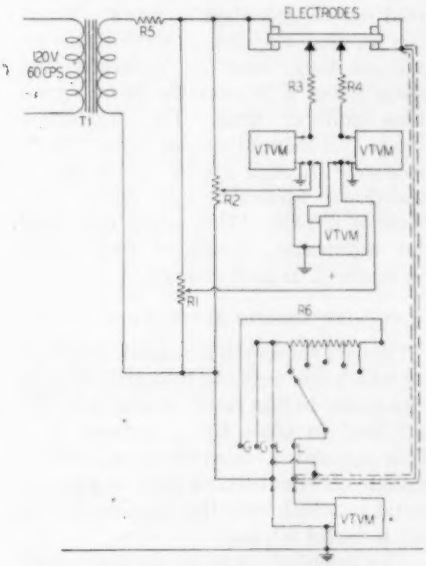

Fig. 6.—A-C. Specific Impedance Measuring Circuit.

T1 1:1 isolation transformer, a least 15 w.
R1, 2 10,000 ohms wire-wound potentiometers. 10 w.
R3, 4 10^7 ohms carbon resistances, 1 w.
R5 1000 ohms wire-wound resistance, 25 w.
R6 Ayrton shunt. 10,000 ohms total. Multipliers 1, 0.1, 0.01, 0.001, and 0.0001. Maximum currents required: 0.1 ma., 1 ma., 10 ma., 100 ma., 120 ma.
VTVM Vacuum tube voltmeter. Full scale 0.03, 0.1, 0.3, 1, 3, 10, 30, 100, 300 v. Input impedance 1 megohm and 15 $\mu\mu$f.

Mechanical Operation of the Bird Film Applicator

By A. E. Jacobsen[1] and H. S. Jensen[1]

PROMPTED by the need for suggesting to the paint industry the most reliable methods for the preparation of uniform paint films, the New York Paint and Varnish Production Club made a survey of the methods employed and then investigated the merits of each.[2]

The survey showed that the doctor blade type of film applicator was the

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] Titanium Division, Research Laboratory, National Lead Co., Sayreville, N. J.

[2] N. Y. Paint and Varnish Production Club Official Digest, Federation of Paint and Varnish Production Clubs Convention issue 1940.

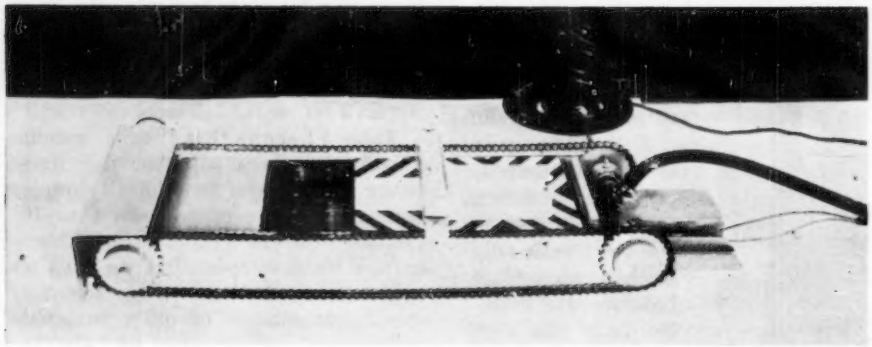

Fig. 1.—Mechanically Operated Bird Film Applicator in Operation.

most commonly employed and that the most widely used type was the Bird Film Applicator (sometimes referred to as the Bradley Blade). This film applicator is well known and therefore need not be described in detail. Findings of this Production Club's survey indicate that, manually operated, the blade is not a dependable tool to produce uniform films. The difficulties due to this manual operation have been overcome through use of an automatic drawdown apparatus, of which the blade is a part. This paper describes the automatic applicator and gives examples of its performance.

Automatic Applicator

Figure 1 shows the automatic applicator which was designed primarily for use with paper hiding power charts (8 by 15 in.) held in place by a vacuum box. This apparatus, however, can accommodate other substrates such as glass or metal in which case the vacuum box is not a useful adjunct.

The essential parts of the apparatus illustrated consist of a vacuum box approximately 9 by 20 in. with a plate glass insert 8 by 15 in. in which fifty-six $\frac{1}{8}$-in. holes have been drilled. The holes are sufficiently close to permit uniform vacuum to hold down the paper chart. At the rear of the box is an outlet to which the vacuum line is attached. At each end of the box are shafts with gears to accommodate a roller chain, the rear shaft being connected to a motor with reducing gears to give 6 rpm.[3] A Bird applicator blade is placed in a weighted holder which in turn is held in position by means of pins which fit into the chain. The blade is drawn over the surface by the moving chain. On the side of the box is a time switch (not shown in picture) which stops the blade at the end of 15 sec. (the time required for the blade to move from the top to the bottom of the box). An "L"-shaped piece of sheet metal is fastened to the front end of the support of the box as a protective shield. While a 6-in. wide Bird Film Applicator blade has been used, other blades of similar construction may be employed in like manner.

Examples of Performance:

The performance of the automatic film applicator is most satisfactorily shown by examples. Table I gives the determined dry film thickness of several paints applied on plate glass using 6-in. Bird Film Applicator blade. The dry film thickness was determined on six areas by means of an Ames gage. The location of these areas is shown on the panel illustrated in Fig. 2.

TABLE I.

Type of Paint	Wet Film Delivery, mils	Dry Film Thickness mils, at Several Locations on Panel					
		A	*B*	*C*	*D*	*E*	*F*
1. White enamel	3	1.7	1.7	1.7	1.7	1.7	1.6
2. White enamel	3	1.6	1.7	1.6	1.7	1.7	1.7
3. Flat white...	3	2.3	2.3	2.3	2.4	2.2	2.4
4. Outside white	3	3.1	3.2	3.1	3.2	3.2	3.2

Table II gives the determined dry film thickness, using both an Ames gage and a G.E. type *B* magnetic gage, of an enamel applied with a 6-in. blade delivering a 3-mil wet film over a chromium plated steel panel. In the case of this panel, eight locations were measured. The areas were first measured for film thickness with the magnetic gage and then with the Ames gage.

TABLE II.

	Dry Film Thickness, mils, at Several Locations on Panel							
	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*
Magnetic gage..	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Ames gage.....	2.3	2.2	2.2	2.2	2.3	2.2	2.2	2.3

One of the most accurate means of determining uniformity of film thickness is the measurement for uniformity of "show-through" of a black background over which a white paint has been applied. It is not deemed necessary to go into full details of the experiments, except to mention that the paint was applied at 3-mils wet film thickness over a lacquer-coated chart having alternate 2-in. black and white squares and that reflectance measurements were made to determine the "show-through" over the black areas. Eight of the black squares were photometered with the Hunter Multi-Purpose Reflectometer, and it was found that the maximum deviation from the averge thickness of the paint applied over these areas was within ±2 per cent.

While the above examples show the uniformity of film thickness attained with the automatic film applicator, it is of particular value when making hiding power determinations in duplicate to obtain uniformity in weight of film applied from chart to chart.

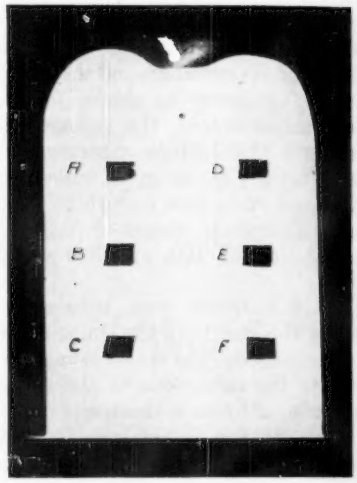

Fig. 2.—Location of Areas Measured for Film Thickness for Paint Applied Over Glass

Table III gives the dry weight of an enamel and a flat paint applied with Bird Film Applicators delivering various film thicknesses of paint over lacquer-coated charts. The original charts were 15-in. long, but prior to determining the amount of weight applied, 3 in. of the chart from the top and 3 in. of the chart from the bottom were discarded. The weight of the applied film therefore represents 54 sq. in. Three paper charts were used for each paint at each film thickness.

TABLE III.

Wet Film Delivery, mils	Weight of Dry Enamel, g.		
	Chart I	Chart II	Chart III
1.5.....	0.95	0.95	1.00
2.0.....	1.20	1.25	1.30
3.0.....	1.95	1.95	1.95
4.0.....	2.75	2.80	2.80
Wet Film Delivery, mils	**Weight of Dry Flat Paint, g.**		
	Chart I	Chart II	Chart III
1.5.....	1.85	1.90	1.95
2.0.....	2.65	2.65	2.70
3.0.....	4.20	4.20	4.25
4.0.....	5.85	5.90	5.95

[3] The motor shown in the illustration is a converted electric fan with the shaft of the oscillating mechanism attached to the shaft on which the driving gears are fixed.

Petroleum Technology

A Review of Reviews by W. T. Gunn

REVIEWS OF PETROLEUM TECHNOLOGY, Volume 7 (Covering 1941–45), F. H. Garner, O.B.E., Ph.D., F.R.I.C., Honorary Editor, E. B. Evans, Ph.D., M.Sc., F.R.I.C., Honorary Associate Editor, George Sell, Publications Secretary. Published by The Institute of Petroleum, 26 Portland Place, London, W. 1. 499 pages of text and references, 19 topical reviews, each by a recognized authority on the subject. Price, 21*s.*, post free.

The appearance of Volume 7 in this series should be welcomed by all technologists who need to have a reference volume at hand where they can look for a brief review and a ready list of references on any specialized subject in the whole field of petroleum technology. In a review of this volume one cannot hope to summarize the contents which in themselves are summaries of the material published during the years 1941–1945. This review can only give a brief listing of the topics covered.

Each topic (there are no numbered chapters) contains its own synopsis and is followed by a list of references. Some of the lists of references are complete, others are not, and one author calls attention to the fact that the literature on his subject (Analysis and Testing) was too voluminous to permit an exhaustive review. The topics covered are listed below:

Petroleum Geology, by G. D. Hobson. 14 pages, 64 literature references. A competent review.

Geophysics, by J. McG. Bruckshaw. 15 pages, 63 literature references. Carefully written and carefully documented.

Drilling, by R. B. Shearn and Alfred Nissan. 15 pages, 225 literature references. Appears to be an excellent summary.

Production Engineering, by R. B. Shearn and Alfred Nissan. 18½ pages, 355 literature references. These authors are thorough.

Petroleum Transportation in the U.S.A., by George R. Wilson. 10 pages, 6 literature references. Evidently little was published on petroleum transportation during the period covered. A good story but it isn't technology.

Refinery Process Developments, by Gustav Egloff and R. F. Davies. 25 pages, a two-page chart, 83 literature references. Reviews commercial process operations, little technology.

Analysis and Testing, by C. F. McCue, J. H. Putman, and E. H. Wild. 43 pages, 518 literature references. A comprehensive if not exhaustive review.

Chemistry of Petroleum, by A. Winward. 16 pages, 200 literature references. A competent review.

Physics of Petroleum, by J. Tadayyon, G. F. Wood, and Alfred H. Nissan. 15 pages, 307 literature references. An excellent summary and what appears to be a complete list of references.

Natural Gas, Liquefied Petroleum Gas, and Natural Gasoline, by Thelma Hoffman. 8 pages, 57 literature references. A trilogy on which the literature is not extensive, but which is competently reviewed.

Benzole, by W. H. Hoffert and R. A. Fraser. 30 pages, 461 literature references. A competent and interesting review but it isn't petroleum.

Alternative Fuels—Part I—Fuels Produced by Hydrogenation and Synthetic Processes, by C. M. Cawley and C. C. Hall. 21 pages, 133 literature references. A careful review of publications on hydrogenation processes including Fischer-Tropsch.

Alternative Fuels—Part II—Low- and Medium-Temperature Carbonization and Other Substitute Fuels, by W. H. Cadman. 43 pages, 169 literature references. A brief review of the extensive literature on the several processes that are not extensively commercialized—peat, shale, coal, vegetable oils, and miscellaneous processes for the production of liquid and gaseous fuels.

Specifications for Service Fuels, by F. N. Harrap. 22 pages, 11 appendices. British specifications.

Diesel Fuels and Gas Oils, by Alfred Wilson. 10 pages, 56 literature references. Excellent review with some more or less apt opinion.

Wartime Specifications for Lubricants, by J. R. Taylor. 15 pages, no references. An interesting narrative.

Asphaltic Bitumen and Road Materials, by W. W. Goulston. 9 pages, 64 literature references. Covering manufacturing, properties, and application of asphalt and bitumen.

Special Products, by C. L. Gilbert. 62 pages, 496 references, covers a hodgepodge of miscellany too numerous to list. A valuable contribution.

Petroleum Literature, by G. P. Kitt. 8 pages, 224 references. A valuable list.

The book also includes a voluminous "Name Index" and an extensive "Subject Index" which are a useful adjunct to any publication of this nature.

By any standard this is a monumental work. The Institute of Petroleum is to be congratulated on the accomplishment of a worth-while contribution.

W. T. GUNN

Vat Dyestuffs and Vat Dyeing

THE author of this book, M. R. Fox, has succeeded in compressing into a small volume, a surprisingly large amount of useful information, much of it evidently obtained from the technical journals and the literature furnished by the dye manufacturers, which appears to be well selected and reasonably up to date. A brief historical note on the natural vat dyes (indigo, woad, etc.) is followed successively by chapters on the chemistry of the vat dyes, their fastness and other properties, and their application to the various fibers in dyeing, printing, and discharging. The leuco vat esters (Indigosols) are also discussed at considerable length. A chapter of dyeing and printing machinery, an excellent review of methods for the identification of vat dyes in substance and on the fiber, and a table of all the known vat dyes grouped according to chemical types complete the volume.

This is apparently the first book which has appeared, dealing exclusively with the vat dyes. It will be a welcome addition to most textile libraries. Copies can be procured at 20 shillings, from the publisher.—W. H. CADY

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